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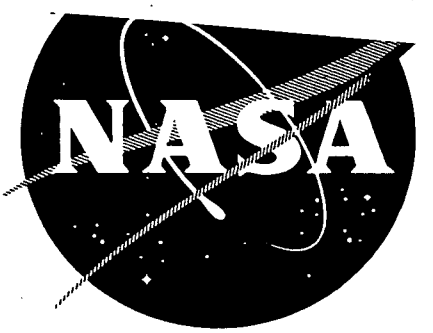
REFERENCE EARTH ORBITAL RESEARCH AND APPLICATIONS INVESTIGATIONS

(BLUE BOOK)

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REFERENCE EARTH ORBITAL

RESEARCH AND APPLICATIONS INVESTIGATIONS

(Blue Book)

VOLUME IV

EARTH OBSERVATIONS

15 January 1971

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

PREFACE

The purpose of the preliminary edition of the "Reference Earth Orbital Research and Applications Investigations" set forth in this document is to:

a. Provide criteria, guidelines, and an organized approach for use in the Space Station and Space Shuttle Program Definition Phase and ancillary studies in designing a flexible, multidisciplinary orbiting space facility and logistics system.

b. Define a manned space flight research capability to be conducted in earth orbital Space Stations and Shuttles.

c. Provide a basis for potential follow-on programs.

The term "Functional Program Element" (FPE) used in this document describes a gross grouping of experiments characterized by the following two dominant features:

a. Individual experiments that are mutually supportive of a particular area of research or investigation, and

b. Experiments that impose similar and related demands on the Space Station Support Systems.

The research and applications investigations as set forth herein depart from a heterogeneous collection of individual experiments and are designed toward a "research facility" and "module" approach. The term FPE and "module" are used somewhat interchangeably in this publication although this relationship is unintentional. Thus, a particular FPE may be described which does not fully utilize the capability of a complementary module but would, however, permit flexibility in experiment planning.

Functional Program Elements and experiments covered in this document are envisioned for flight with the initial Space Station and the Space Shuttle. Only those FPE's and experiments which can reasonably be expected to be accomplished during the first few years of the Space Station and Space Shuttle have been described in detail in this document. However, for the most part, these FPE's are considered to be open-ended so that their utility could be extended.

This publication is applicable to all NASA program elements and field installations involved in the Space Station and Space Shuttle program.

The supply of this document is limited. Therefore, for those procurement actions involving only a certain portion (or portions) of this handbook, the cognizant NASA installations shall abstract from this handbook only such portions as apply to a given RFP or contract action.

This publication was prepared in conjunction with NASA Headquarters Program Offices and field installations involved in payload planning and with industry participation. It is an updated and revised version of the Candidate Experiment Program for Manned Space Stations, NHB-7150.xx, dated September 15, 1969 and the changes thereto dated June, 1970. These earlier versions are hereby cancelled.

The material contained in each volume has been produced under the guidance of Review Groups composed of scientific personnel at NASA Headquarters, MSFC, LaRC, MSC, LeRC, GSFC and ARC. The purpose of this effort was not only to revise and update the experiment programs but also to establish the Space Shuttle as well as the Space Station requirements.

Volume I, Summary, presents the background information and evolution of this document; the definition of terms used; the concepts of Space Shuttle, Space Station, Experiment Modules, Shuttle-sortie Operations, and Modular Space Station; and in Section IV, a summary of the Functional Program Element (FPE) requirements is presented.

Volumes II thru VIII contain detailed discussions of the experiment programs and requirements for each discipline. The eight volumes are:

Volume I	Summary
Volume II	Astronomy
Volume III	Physics
Volume IV	Earth Observations
Volume V	Communications/Navigation
Volume VI	Materials Sciences & Manufacturing
Volume VII	Technology
Volume VIII	Life Sciences

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INTRODUCTION

The Earth Observations discipline consists of the single Functional Program Element (FPE): Earth Observations Facility. The stress in this revision of the FPE has been to update the sensor specifications and to shift some of the emphasis from sensors to experiments to be done aboard the Facility.

The Earth Observations Facility will include provision for data acquisition, sensor control and display, data analysis, and maintenance and repair. Its function is to provide scientists in universities, industry and government the means for making observations of Earth utilizing the unique capabilities that man can provide to a laboratory in space. The Facility is research and development in nature with a potential for operational applications.

Seven areas in which Earth Observation experiments will be done are developed and the objective, measurements, sensors and data are defined for each area. From these individual area specifications the Facility requirements for sensor numbers, weight, volume, power, data, orbit parameters and crew skills are established. The results are summarized in two ways:

a. A core facility that consists of the most severe requirements for weight, power, etc., increased by 10% to account for growth.

b. The range of requirements in terms of the minimum and maximum requirement for all seven experiment areas.

The following table lists the crew skills from which those skills applicable to Earth Observations are taken.

Crew Skills

1. Biological Technician
2. Microbiological Technician
3. Biochemist
4. Physiologist
5. Astronomer/Astrophysicist
6. Physicist
7. Nuclear Physicist
8. Photo Technician/Cartographer
9. Thermodynamicist
10. Electronic Engineer
11. Mechanical Engineer
12. Electromechanical Technician
13. Medical Doctor
14. Optical Technician
15. Optical Scientist
16. Meteorologist
17. Microwave Specialist
18. Oceanographer
19. Physical Geologist
20. Photo Geologist
21. Behavioral Scientist
22. Chemical Technician
23. Metallurgist
24. Material Scientist
25. Physical Chemist
26. Agronomist
27. Geographer

SECTION 1

EARTH OBSERVATIONS FACILITY

1.1 GOALS AND OBJECTIVES

The purpose of the Earth Observations Functional Program Element (FPE) is to define the basic requirements for a manned facility that utilizes the unique capabilities of man in the orbital survey of the Earth and its environment. The goals of the Earth Surveys Program include:

a. Definition of the Earth's geometry, surface characteristics and dynamic body properties.

b. Understanding the physics of the atmosphere, the prediction of weather and the establishment of a basis for weather modification and climate control.

c. Responsible management of the Earth's resources and the human environment.

These goals are tied to broad objectives related to:

a. Providing a precise and accurate geometric description of the Earth's surface and determining time variations of the geometry of the ocean surface, the solid Earth, and other geophysical parameters.

b. Observing, on a global scale, the composition, structure and energetics of the atmosphere to understand atmospheric interactions: 1) within the atmosphere; 2) in response to solar inputs; and 3) at the air-Earth surface interface; and to establish a basis for experiments in longer-range forecasting and modification of the weather.

c. Continuing developmental support to operational meteorological satellite systems and developing meteorological technology to support aeronautical and space systems design, testing and operations.

d. Determining the performance of remote sensors in identifying Earth resources and establishing signature recognition criteria, and developing sensors, subsystems and experimental spacecraft for application to future operational satellite systems.

e. Determining the scope and configuration of an operational user-oriented Earth resources survey system including ground, airborne and space components.

f. Evolving a complete data system, from the acquisition of remotely sensed data to the eventual application by a user to a specific problem, including techniques and formats for data handling and utilization.

1.1.1 AREAS OF INVESTIGATION. The goals and objectives cited above will be attained in part by experiments and investigations performed by the crew of the Earth Observations Facility, and the following is a representative list of areas in which these experiments might be performed. The principal source of these areas of experimentation was the 1970 NASA Langley Research Center's Earth Orbital Experiment Program and Requirements Study. Each area includes a number of research clusters from the study that have common objectives and/or observation techniques, sensors, user application, etc. Also included are suggestions for experiments offered by members of the Earth resources remote-sensing community in government, universities and industry. The seven areas of experimentation selected are:

a. Meteorology and the Atmospheric Sciences

b. World Land Use Mapping

c. Air and Water Pollution

d. Resource Recognition and Identification

e. Natural Disaster Assessment and Anomalies

f. Ocean Resources

g. Special Research

1.1.2 ACCOMMODATION MODES. The data-gathering operation of the facility can be in conjunction with either a long-lived Space Station or a Space Shuttle with a short in-orbit stay time. The orbit altitude should be as low as is compatible with the required facility lifetime, but it is expected to be greater than 185 km (100 n. mi.). For most of the experiments, a maximum latitude of 50° is satisfactory, since it includes the truth sites in the United States and the major portion of the populated world. For some experiments, a polar orbit is the best choice. In general, observations are made between sunrise and sunset because almost all experiments require photography or visual sighting. At least two crewmen always are required for data collection and evaluation — preferably one technician and one resource scientist. Since most of the experiments include several Earth resource disciplines (for example, Land Use Mapping which includes geography, agronomy and geology), the scientist should be knowledgeable in each discipline involved in the experiment.

1.1.3 RELATED PROGRAMS. Space photography and photo analysis techniques will draw heavily on the results of the manned space program summarized below.

1963	Mercury	Color Photography	
1965-66	Gemini	Color Photography	
1967-69	Apollo	Multispectral Photography Experiment	SO-65

The meteorological satellite programs, i.e., Nimbus, ATS and TIROS, have developed television, radiometer, and spectrometer sensors. By utilizing the special capabilities of man, more varied, yet precise, measurements and observations of specific ground targets can be made from the facility.

The NASA Earth Resources Aircraft Program is developing remote sensing systems and techniques having potential practical application for the measurement of various characteristics of Earth. Since the aircraft program sensors well may be the predecessors of the sensors used aboard a manned space facility, a preliminary list of them from Reference 2 is included in Table 1-1 to indicate the general type of sensors that possibly will be available to the space program as off-the-shelf hardware.

The principal objectives of the Earth Resources Technology Satellite (ERTS) Program are to flight test a television camera, multispectral scanner and ground data collection system, and to provide Earth resources data to the user community. Advanced versions of these sensors are part of the Earth Observations Facility, too, and the ERTS program will serve as a test bed for the initial development of sensing and data management techniques. The facility will continue the development of the various sensors

Table 1-1. Earth Resources Aircraft Program Sensors

	NP3A NASA 927	NC130B NASA 929	RB47F AF 13501
Camera Systems	1. Two RC-8 metric cameras with a 9 x 9 inch film format. 2. Four KA-62 matched-lens multiband cameras. 3. Three boresight cameras used in conjunction with the imaging radar, the multi-frequency radiometer, and the infrared spectrometer/ radiometer.	1. Two RC-8 metric cameras with a 9 x 9 inch film format. 2. Six Hasselblad multiband cameras. 3. Three boresight cameras used in conjunction with the imaging radar and the imaging radiometer.	1. Two RC-8 metric cameras with a 9 x 9 inch film format. 2. Six Hasselblad multiband cameras. 3. One boresight camera for precise and concurrent ground track coverage for the IR instruments.
Line Scanners and Infrared Systems	1. One RS-14 dual channel scanner operating at 3.0 to 5.5 and 8 to 14 microns. 2. One 10 to 12 microns radiometer. 3. One precision radiation thermometer, 8-14 microns. 4. One IR spectrometer/ radiometer operating at 6.7 to 13.2 microns.	1. One Recon IV single channel scanner operating at 8 to 14 microns. 2. One precision radiation thermometer. 3. One 24 channel multi-spectral scanner that covers 0.34 to 13.0 microns; due 1971.	1. One RS-7 single channel IR scanner operating at 8-14 microns. 2. One 6.7-13.2 micron filterwheel spectrometer. 3. One 10 to 12 micron radiometer.
Active Microwave Systems	1. Two radar scatterometers operating at 0.4, and 13.3 GHz.	1. One radar scatterometer operating at 13.3 GHz	New systems in the visible infrared and microwave regions, e.g., the scanning imaging spectroradiometer, will be added as the program evolves.
Microwave Sensors	1. One four channel microwave radiometer operating in the 1 to 21 cm range. 2. One 10.6 GHz passive microwave imager.		
Laser Systems	1. One 6328Å laser profiler.		

and information management systems to the point that, between the two programs, an operational system can be implemented.

Another source of sensor hardware, measurement technology, and data analysis techniques for the Earth Observations Facility will be the NASA Advanced Airborne Flight Experiments (AAFE) program of the Langley Research Center. Some of the work being supported by the 1970 AAFE program is listed below.

a. Visible Radiation Polarization Measurement From A Satellite

b. Satellite Microwave Radiometry to Sense the Surface Temperature of the World Ocean

c. MIT Aeronomy Experiment

d. Radiometric Vertical Sensor

e. Microwave Occultation Experiment

f. Composite Microwave Radiometer-Scatterometer

g. Carbon Monoxide Pollution Experiment.

The first manned Earth resources laboratory to orbit will be Skylab A. Its goals are to advance the development of remote data acquisition techniques and to obtain Earth resources data. Five sensors are being developed for Skylab A, and improved versions of the sensors used are expected to be part of the Earth Observations Facility:

S-190	Multispectral Photographic Facility
S-191	Infrared Spectrometer
S-192	Multispectral Scanner
S-193	Microwave Radiometer/Scatterometer/Altimeter
S-194	L-Band Microwave Radiometer

1.2 PHYSICAL DESCRIPTION

1.2.1 FACILITY. The Earth Observations Facility will include provision for data acquisition, sensor maintenance and repair, sensor control and display, and data analysis, as portrayed in Figure 1-1. Its function is to provide scientists in universities, industry and government the means for making observations of Earth by utilizing the unique capabilities that man can provide to a laboratory in space. The facility is research and development in nature with a potential for operational applications.

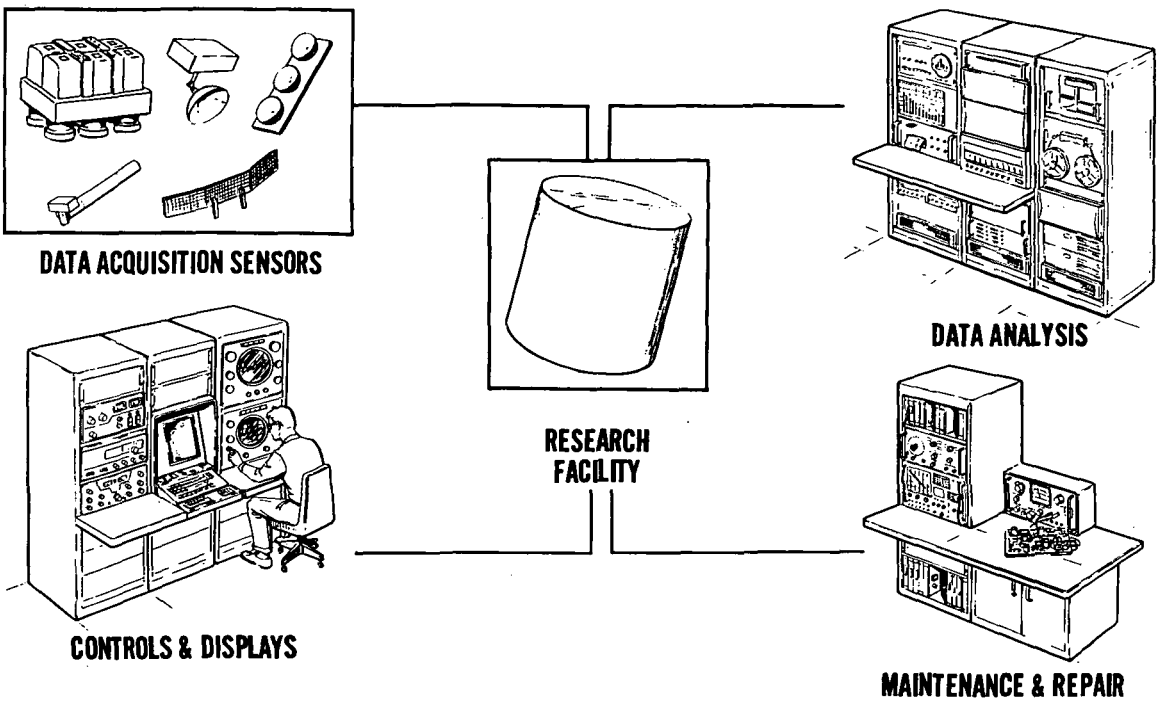


Figure 1-1. Earth Observations Facility Components

It is emphasized that the purpose of the Blue Book is to be a source of generic requirements for support of an Earth Observations Facility by a RAM, rather than a firm selection of particular sensors or experiments. Sensors and experiments actually to be flown are under study and cannot be defined in detail at this time. The use of the FPE, therefore, should be in the designing of a flexible facility to conduct experiments using sensors and data analysis techniques of the types discussed, e.g., Earth and horizon looking, large data rates, and large antennas, rather than as a source of specific instruments or experiments.

Data acquisition is primarily by the sensors located aboard the facility. These sensors fall into three groups that have general applicability and a fourth group that is unique to the particular research. Included in the first groups are imagers, radiometers and spectrometers, and included in the latter group are polarimeters, sferics detectors and optical radar. Research in both multisensor and multispectral sensing will be done, so provision must be made for operating sensors simultaneously without mutual interference. In addition, the sensors must be designed and mounted so that various portions of the total band pass of an individual sensor can be used simultaneously. The facility design must be such that there is no obstruction in the field of view. Sensors must be mounted so they are accessible to the crew for maintenance and modification, preferably without having to don a space suit. It may be necessary to point the sensors through angles as great as $\pi/3$ radians (60 degrees) from the local vertical, and the sensor mountings must permit this.

Sensor controls will provide the means to operate several sensors simultaneously or to select various portions of the total passband of a multispectral sensor. The performance displays will enable the crew to check the sensors for proper operation and to monitor all of the raw data for electronic quality and selected data for quick-look evaluation. The maintenance and repair unit is used for the receipt, servicing, repair and modification of the instrumentation and should be about 10 m^2 (100 ft^2) in area.

The data analysis unit should have the capability to store, call up, and display all data. It will utilize the capabilities of man to reduce the amounts of redundant, superfluous, or low-quality data that is collected or transmitted. Man will review past data for quality and, where the quality is poor, recommend observation techniques that will not be subject to the same degradation. If low quality data are taken inadvertently, he will screen out these data so they are not transmitted to the surface. In addition to screening, data compaction techniques also will be employed to reduce the amount and raise the quality of the transmitted data. The equipments will provide for monitoring the data for basic electronic quality and screening it for experimental usefulness, and also will include computer, photo development, and photo analysis capabilities. About 12 m^2 (135 ft^2) of floor space will be required.

1.2.2 SENSOR REQUIREMENTS. All of the sensors required by the seven Experimental Areas cited in the preceding section are listed in Table 1-2. Mechanical, electrical and resolution characteristics of each sensor are specified, in order to drive out the design requirements of the facility, but these specifications are only representative of a sensor of the particular class or type. The first dimension of the size is along the flight path and the last dimension is toward nadir. The sensors are grouped by class, i.e., imagers, radiometers, spectrometers and experimental. The experimental class is composed of those sensors that are unique to particular experiments, and they usually are less well developed than the others. Sensors 2, 3, 7, 10 and 11 will be mounted on gimballed platforms that can be trained either automatically or by the astronaut by means of the telescope. Each sensor and support item is discussed in the balance of this section.

The total spectral range of each sensor is depicted in Figure 1-2. In most instances the broad optical bands are divided into the ultraviolet 0.3 μm and 0.4 μm, the visible 0.4 μm to 0.7 μm, the short wavelength infrared (SWIR) 0.7-2.4 μm, and the long wavelength infrared (LWIR) 6-15 μm. The sensors should be designed so the crew can modify these bands to some extent to fit the needs of the individual experiments.

The long wavelength infrared sensors may use one or several detectors, depending upon the design. The weight per minute of liquid nitrogen listed under cryogenics is for each detector that is refrigerated. The amounts of film and tape used are listed in Table 1-2.

Table 1-2. Requirements Summary

Sensor	A. SENSOR SPECIFICATIONS: Dimensions Size[1] cm (in)	Volume m^3 (ft^3)	Mass[2] (Wt) kg (lb)	Power Stand-by watts	Power Avg watts	Power Peak watts	Attitude Pointing ±mrad (±deg)	Attitude Rate mrad/sec (deg/sec)	Cryogenics Rate g/min (lb/min)	Sensor Capabilities Range Spectral	Sensor Capabilities Range FOV rad (deg)	Sensor Capabilities Resolution Spatial mrad	Sensor Capabilities Resolution Spectral	Sensor Capabilities Resolution Temp °K	C. DATA Media	Size mm	Format mm	Scientific Generation Rate Per Channel or Camera Code bits	Digital bps	Film frames/min	Film[8] or Tape cm/min	No. Ch. or Cameras	Dig. Rate All Ch. bps	Engineering Code bits	Dig. Rate/Ch. bps	No. Ch.	Dig. Rate All Ch. bps
IMAGERS																											
1. Metric camera	115×78×127 (46×31×51)	1.2 (42)	250 (550)	50	500	780	17 (1)	0.8 (0.05)	None	0.4-0.9 μm	0.74×1.1 (41×62)	0.4	-		film	240 (9 1/2 in)	224×350 (9×14 in)	-	-	2	75	1	-	8	0.8	22	18
1a. Stellar Camera															film	70	57	-	-	2	15	4	-	Included in Metric Camera			
2. Multispectral camera[3]	60×60×37) (24×24×15)	0.14 (5)	265 (590)	30	170	600	35 (2)	0.8 (0.05)	None	0.4-0.9 μm	0.37×0.37 (21×21)	0.8	0.1 μm	-	film	70	57	-	-	2.7	45	6	-	8	0.8	36	29
3. Multispectral television[3,4]	73×73×73 (29×29×29)	0.068 (2.4)	50 (110)	1	200	250	8 (0.5)	3.5 (0.2)	None	0.4-0.8 μm	0.17 (10)	1.3	100 Å	-	tape	25	multi-track	8	1.3 M	-	2000	1	1.3 M	8	0.8	10	8
4. Multispectral scanner[4]	83×48×150 (33×19×60)	0.6 (21)	135 (300)	60	190	190	44 (2.5)	0.8 (0.05)	0.32 (7×10^{-4})	0.4-12.5 μm	0.12 (±6.6)	0.06 to 0.12	1 μm	1	tape	25	multi-track	9		-			50 M	8	40	33	1300
5. Passive microwave scanner	420×30×420 (160×12×160)[5]	5.6 (197)	114 (250)	30	175	175	17 (1)	0.8 (0.05)	None	10 GHz	0.35 (±20)	8	-	0.5	tape	25	multi-track	10	2000	-	30	1	2000	8	0.8	12	96
6. Microwave radar	450×13×12[5] (180×5×5)	0.115 (41)	135 (300)	50	1000	1000	17 (1)	0.8 (0.05)	None	5-15 GHz	$0.087\times2\times10^{-5}$ (5×0.001)*	0.02	-	-	film	70	57	-	150 M	-	900	1		8	0.8	17	14
RADIOMETERS																											
7. Multispectral[3]	25D×60 (10D×24)	0.04 (1.6)	18 (40)	2	20	20	8 (0.5)	5 (0.3)	0.32 (7×10^{-4})	0.5-13 μm	0.003 (0.02)	0.3	0.3 μm	0.2-0.5	tape	25	multi-track	9	900	-	14	3	2700	8	0.8	20	16
8. Microwave[6]	900D×100[5] (360D×36)	9.4 (330)	200 (450)	40	160	160	17 (1)	0.8 (0.05)	None	1.5-60 GHz	0.017 and 0.07 (1 and 4)	4-26	-	-	tape	25	multi-track	12	96	-	6	4	384	8	0.8	20	16
9. Scatterometer/ radiometer[7]	115D×50[5] (44D×20)	0.3 (10.5)	74 (163)	59	153	300	44 (2.5)	0.8 (0.05)	None	13.5 GHz	±0.9 (±52)	30	-	1	tape	25	multi-track	10	10k	-	52	3	30k	8	0.8	21	17
SPECTROMETER																											
10. Multispectral[3]	50×75×45 (20×30×18)	0.17 (6.3)	160 (350)	120	170	250	17 (1)	0.8 (0.05)	None	0.4-15.5 μm	0.001 (0.057)	1	0.2 μm	1	tape	25	multi-track	10 10	6.8k[9] 40k[10]	-	100 600	4 1	27.2k 40k	8	0.8	15	12
11. Aeronomy[3]	88D×200 (35D×80)	1.31 (46.6)	61 (136)	260	260	650	35 (2)	0.17 (0.01)	None	0.1-100 μm	0.003 (0.2)	3.5	0.5-20 cm^{-1}	2	tape	25	multi track	12 18	40k 20k	-	600 300	1 1	40k 20k	12	36	14	500
EXPERIMENTAL																											
12. Polarimeter	30×30×60 (12×12×24)	0.057 (2)	18 (40)	12	20	45	8 (0.5)	3.5 (0.2)	None	0.38-0.58 μm	2.1 (120)	52	100 Å	-	tape	25	multi-track	10	160	-	3	15	2400	8	16	20	320
13. Sferics Detector	45D×12.5[5] (18D×5)	0.08 (2.8)	10 (22)	1	6	6	35 (2)	0.8 (0.05)	None	610 MHz	2:1 (120)	1.04	1 MHz	-	tape	25	multi-track	10	300	-	4	1	300	8	0.8	10	8
14. Absorption Spectrometer	30×30×30 (12×12×12)	0.028 (1)	13.5 (30)	1	15	18	0.8 (0.05)	0.8 (0.05)	None	0.28-0.50 μm	0.017 (1)	17	8 Å	-	tape	25	multi-track	9	450	-	7	3	1400	8	0.8	6	5
15. Optical Radar	65×68×65 (27×28×26)	0.38 12	167 (370)	60	635	635	0.8 (0.05)	0.8 (0.05)	None	0.69 μm	0.0006 (0.034)	0.6	20 Å	-	tape	25	multi-track	24	3	-	1	1	3	8	0.8	10	8
B. SUPPORT SPECIFICATIONS																											
16. Observation Telescope	240×53×45 (95×21×18)	0.23 (8.2)	112 (250)	50	240	240	17 (1)	0.8 (0.05)	None	0.35-0.72 μm	0.007&0.52 (0.4&30)	0.01-0.042			film	35	30	-	-	0.6	3	1	-	8	0.8	5	4
17. Telescope Computer	60×30×60 (24×12×24)	0.11 (4)	67 (150)	100	300	300			None																		
18. Data Collection	45D×15 (18D×6)	0.006 (0.2)	4.7 (10.5)	1	8	8		NA	None	450 MHz	1.74 (100)	-	4.1 kHz	-	tape	25	-	-	256	-	4	TBD	TBD	8	0.8	5	4
19. Cloud Chamber	30×30×30 (12×12×12)	0.76 (27)	90 (200)	20	200	200		NA	TBD	-	-		NA		film& tape	To be determined by experimenter											
20. Controls and Displays	120×45×120 (48×18×48)	0.7 (25)	360 (800)	100	1200	1200		NA	None	NA			NA														
21. Data Analysis Electronic	120×45×90 (48×18×36)	0.6 (20)	299 (665)	20	400	400		NA	None	NA			NA														
Photo	60×60×150 (24×24×60)	0.6 (20)	302 (670)	30	500	500		NA	None	NA			NA														
22. Maintenance and Repair	60×60×150 (24×24×60)	0.6 (20)	258 (575)	-	50	300		NA	TBD	NA			NA														

NOTES

1. Dimensions are for principal sensor component; see sensor description for complete size details.
2. Weight does not include expendables or consumables.
3. Platform mounted.
4. Dual mode.
5. Size is tabulated for antenna only.
6. Two trainable antennas (see text).
7. Includes altimeter.
8. Tape length assumes 10^4 to 10^5 bits per 25 mm (inch).
9. Visible and IR bands.
10. Ultraviolet bands.

* Effective FOV.

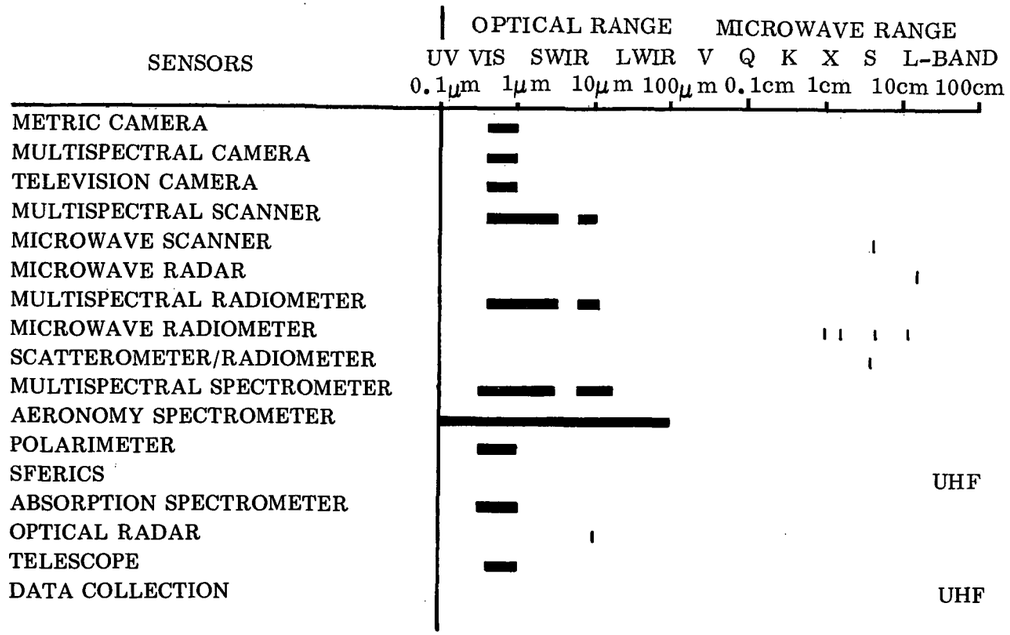


Figure 1-2. Spectral Range of Sensors

1.2.2.1 Metric Camera. A number of aerial cameras are in use by the NASA Aircraft Program and it is expected that one of them will be adapted for use on the Earth Observations Facility. The specifications cited in Table 1-2 are for a single camera, while a set of two metric cameras is needed by some experiments for the simultaneous use of color and panchromatic films.

The metric camera is used, in varying degrees, in each of the Experiment Areas. It is a principal sensor in Land Use Mapping and Resource Recognition where the location of resources and general mapping are to be done. In Weather and Ocean Resources it is used to record the cloud cover and type that is present at the time the experiment is performed. Four stellar-reference cameras are provided as part of the metric camera assembly to ensure that, regardless of the attitude of the carrier vehicle with respect to the Earth and the Sun, at least two stellar cameras will view space. A 55 percent overlap of successive frames is assumed for the metric camera.

1.2.2.2 Multispectral Camera. The camera set consists of six high-quality, matched, f/2.8, 15-cm (6-in) cameras with synchronized shutters and individual film magazines and filters. Data can be taken in discrete spectral bands from 0.4 to 0.9 μm by

varying film and filter combinations. Exposure times can vary from 1/400 to 1/100 second, and framing overlap up to 88 percent can be achieved. (The quoted film use of 45 cm/min per camera assumes a 55 percent overlap.)

Typical uses of multispectral photography are 1) establishment of spectral response criteria for discrimination of lithologic units at small scales, and the compilation and revision of regional geologic, tectonic, and topographic maps, 2) determination of percolation and runoff, moisture-energy exchanges, water pollution, and snow and ice cover, and 3) delineation of broad soil, forest, and other vegetative types for mapping and inventory of the world's agriculture/forestry resources.

1.2.2.3 Multispectral Television Camera. This form of television camera is proprosed for the multispectral sensing of vegetation vigor and of ocean pollution because of its very high spectral resolution capabilities. The scene is focused in the plane of a slit that is located behind the objective lens and oriented so that it lies across the velocity vector of the vehicle. The light is then collimated and passed through a diffraction grating, which spectrally disperses the image in the direction of the velocity vector. The collimated and diffracted beam is then focused on the face of a vidicon. Spectral information for each point is spread by the diffraction grating so that it provides an analog signal covering somewhat more than the entire visible spectrum. Each line scanned, therefore, consists of a series of these signatures, which can be transmitted or recorded as-is, or digitized and then recorded or transmitted. Since the energy from each data point covers the whole spectral continuum, the crew can choose any spectral band, bandwidth, or combinations thereof from which they would like to process data.

The spectrum can be divided into any number of narrow bands, depending on the need for spectral resolution, and 12 bands, each 375 Å wide, is one design point. This land-scanning mode provides sufficient spectral resolution to identify, for example, the chlorophyll absorption bands. In the ocean-color scanning mode, the scan pattern is changed to improve spectral resolution and sensitivity, at the expense of spatial resolution, in order to detect very subtle differences in ocean color. The signal is integrated over a larger area, which permits spectral discrimination in over 20 separate bands of 100 Å each.

1.2.2.4 Multispectral Scanner. The uses of the Multispectral Scanner are, in part:

a. To evaluate the usefulness of multispectral data from space in crop identification, vegetation mapping, land-use determination, soil moisture measurement, contaminated water identification, and surface temperature mapping.

b. To determine the feasibility of using computer spectrum-matching techniques for the identification of Earth resources, e.g., crop species from space.

c. To compare the results of computer identification of scanner imagery with direct photo-interpretation of the scanner imagery in the different spectral bands.

d. To compare and evaluate the imagery from a scanner with the imagery obtained from the multispectral film and television cameras.

The scanner operates in two modes: an ocean mode that has relatively wide spectral bands in the visible and near-infrared with a spatial resolution of 0.06 milliradians, and a land mode with narrow spectral bands and a spatial resolution of 0.12 milliradians. The total data rate is about 50 Mbps. Sizes and weights of the individual components of the scanner are as follows:

	Size		Weight	
	(cm)	(in)	(kg)	(lb)
External Scanner Assembly	80 x 47 x 80	32.5 x 19 x 32	56	125
Internal Scanner Assembly	60 x 37 x 70	24 x 15 x 28	45	100
Electronics Assembly	30 x 30 x 60	12 x 12 x 24	34	75

1.2.2.5 Passive Microwave Scanner. This sensor has a phased-array, dual polarized antenna 4.3 m (14 ft) square, 30 cm (12 in) thick, and weighing about 90 kg (200 lb). Operation frequency will be between 5 and 15 GHz and ground resolution about 8 mrad. The beam looks $2\pi/9$ rad (40 deg) ahead of nadir and scans $\pm\pi/9$ rad ($\pm$20 deg) across the ground track. The electronics are 30 x 30 x 30 cm (12 x 12 x 12 in), weigh about 23 kg (50 lb), and should be located on or close to the antenna. Output can be recorded on tape and/or displayed on a CRT.

The surface mapping capability of the radiometer is applicable to watershed and river basin mapping and ocean/ice, ocean/land and land/snow boundary mapping. Thickness and liquid water content of clouds can be estimated for hydrological applications, and the extent of vegetative cover and of moist-soil zones can be approximated for agricultural applications. Over the ocean, where the surface emissivity is low (0.4), atmospheric water vapor will contribute up to 20 percent of the radiation measured at the satellite. The effect of water vapor has been difficult to segregate in the past and a series of flight tests over the North Atlantic in early 1969 were run to resolve this difficulty. Use of both a 10 GHz and a 19.3 GHz radiometer and dual polarization has been suggested.

1.2.2.6 Microwave Radar (Radar Imager). The radar has a 4.5 x 1.5 m (15 x 5 ft) side-looking antenna estimated to weigh about 45 kg (100 lb). The antenna will look from $\pi/6$ to $\pi/3$ rad (30 to 60 deg) to the side of the ground track. The electronics size is estimated to be 60 x 30 x 30 cm (24 x 12 x 12 in), and the optical-film recorder to be 50 x 25 x 25 cm (19 x 10 x 10 in) in size. Each weighs about 45 kg (100 lb). The exact operating frequency will be determined later, but is expected to be between

5 and 15 GHz. The effective field of view is 0.087 rad (5 deg) in the cross-track direction and 0.02 mrad in the along-track. The swath width from 500 km (270 n.mi.) altitude is 28 km (15 n.mi.). The 50 to 150 Mbit/sec data output for a single polarization can be recorded on 15 cm/sec (30 ft/min) of 70-mm film, assuming a 15.5 kilobits/mm^2 film writing density.

A topic for special research will be the merits of a fully focused synthetic-aperture-type radar. The ground resolution is small – one-half the antenna size – but a range ambiguity phenomenon, due to the large number of pulses in the air at one time, severely reduces the attainable swath width.

1.2.2.7 Multispectral Radiometer. This sensor is a profiler, rather than an imager, and operates in the visible, SWIR or reflective infrared, and the LWIR or thermal infrared. The visible and reflective infrared bands are used as reflectometers to identify surfaces or delineate boundaries by differences in their spectral reflective properties with look angle, solar illumination angle, or polarization. Soil texture and sea surface roughness are examples. The LWIR band is used for the precise measurement of the apparent temperature of a surface. An advantage of having man aboard is that he can choose the best band, portion of a band, look angle, etc., for the particular observation he is going to make. Also, he can train the radiometer directly on the target and take a series of measurements as it passes by.

1.2.2.8 Multifrequency Microwave Radiometer. This is a four-frequency radiometer that utilizes one 9-m (30 ft) diameter by 1-m (3 ft) thick parabolic dish antenna for the 1.4 and 5.0 GHz bands and one 3-m (10 ft) diameter by 0.45-m (1.5 ft) thick dish for the 22 and 31 GHz bands. The beamwidths to the first null are 0.0785 rad (4.5 deg) and 0.0175 rad (1.0 deg). The electronics are packaged in 30 x 30 x 30 cm (12 x 12 x 12 in) and attached to the back of each antenna. The antennae can be pointed. This sensor enables the crew to measure apparent temperatures in the microwave for research in surface temperature, soil moisture content, cloud water content, snow and ice mapping, etc.

1.2.2.9 Scatterometer/Radiometer. The microwave scatterometer/radiometer/altimeter is a combination of a radar altimeter, a radar scatterometer, and a passive microwave radiometer. This sensor will be used to determine sea roughness, boundary of snow melt, and ground moisture after a major rainfall. The scatterometer/radiometer operation is based upon the nearly simultaneous measurements of the radar differential backscattering cross-section and the passive microwave emissivity of the land or sea surface. The system presently operates at a single frequency between 13.4 and 14.2 GHz. It is required that the microwave radiometer and scatterometer be capable of operating independently of each other and independently of the altimeter.

The scan is cross-track and makes use of a single 115 cm (44.5 in) parabolic antenna, mechanically scanned, that forms a pencil beam of approximately 0.0262 rad (1.5 deg). The beam is scanned from one cell to another, dwelling on each cell a predetermined length of time. During this dwell time, the microwave instrument executes in sequence two measurements: a radiometer measurement and a scatterometer measurement. Thus, paired values are collected of the differential backscattering cross-section, the sigma zero, and the total apparent black-body temperature for each illuminated surface cell. The cross-track scan is ±0.218 rad (±12.5 deg) from nadir with provisions for extending to 0.91 rad (52 deg) on either side of the ground track with limited scans forward of nadir. The in-track scan is zero to 0.91 rad (52 deg) along the flight path.

The radar altimeter data output will be digital and must be adaptable to the 10-bit word PCM format and will not exceed 10 kbs.

1.2.2.10 Multispectral Spectrometer. This spectrometer covers the ultraviolet, visible and infrared wavelengths. The objective of the ultraviolet measurements is to discriminate and identify geologic features on the surface of the Earth. This part of the spectrometer consists of an image dissector scanning spectrometer and an integrating electronic-scan imaging system. Energy reflected or emitted from the Earth's surface is collected and routed by beam splitters simultaneously to both the imaging system and the spectrometer. Several individual detectors will sense the intensity or energy in those parts of the ultraviolet and visible spectrum where prominent Fraunhofer Lines are present and measure ultraviolet-stimulated luminescence of natural features by means of the "Fraunhofer line-depth" method. The imaging system will provide pictorial information necessary for identification of the area viewed by the spectrometer, and/or selective identification of features within this area which are highly reflective in the ultraviolet. There is a requirement for calibration by means of a solar-illuminated color disc every three days of use. The visible and infrared portion of the spectrometer can acquire spectra of ground targets of 2 km (1 mi) diameter or less with a one mrad spatial resolution. It will scan through the spectral regions 0.4 to 2.4 μm and 6.2 to 15.5 μm at a rate of 1 second per scan. Spectral selection is achieved by two concentric circularly variable filter wheels. A 30-watt closed-cycle cooling engine chills the HgCdTe long wavelength infrared detector.

The spectrometer can be trained on targets by means of the fore-optics of the Observation Telescope. It views a 1 mrad spot at the center of the 7 mrad field of the telescope, and will obtain data on the reflected and emitted radiance in the visible and infrared from which land use, crop identification, rock and soil identification, and meteorologic interpretations can be made. The sensor will be used in conjunction with the Multispectral Scanner to obtain a geologic map of the Earth.

1.2.2.11 Aeronomy Spectrometer. The Aeronomy Spectrometer is a multidiscipline sensor used in Space Physics aeronomy to observe aurora and airglow and in Earth Observations meteorology to evaluate the effect of the atmosphere on resource signatures. The sensor will measure atmospheric parameters, such as the altitude profile of ozone, nitric oxide and the hydroxyl radical, the solar flux between 1000 and 4000 Å, and temperature and humidity profiles from the surface to 30 km (16 n. mi.). The sensor consists of a Michelson interferometer spectrometer to cover the wavelength range from 1 to 100 μm, and an Ebert-Fastie scanning, grating spectrometer from 0.1 to 1.0 μm. The attitude rate limitation of the aeronomy spectrometer is the most stringent of the sensors: 0.175 mrad (0.01 deg)/sec. The spectrometer is contained within a vacuum housing and uses the Observation Telescope optics and computer. Controls and data recorders are included in the Facility Controls and Display Unit. The major components are the following:

	Size		Volume		Weight	
	(cm)	(in)	(m^3)	(ft^3)	(kg)	(lb)
Housing	88 dia x 200	35 dia x 80	1.27	45	54	120
Electronics	22 x 40 x 50	9 x 16 x 19	0.04	1.6	7	16
			1.31	46.6	61	136

1.2.2.12 Spectral Polarimeter. This sensor will make quantitative measurements of the intensity and polarization of the light emerging from the top of the Earth's atmosphere as a function of wavelength. These measurements then will be part of a theoretical treatment of radiation transfer in Earth's atmosphere, including the effects of surface or cloud reflection. Studies performed to date show that the polarization parameters, e.g., Stoke's Parameters, of the emergent radiation are indicative of the type of surface soil or rock and of atmospheric constituents. If sufficient data are obtained with high precision, these can serve as a basis for the development of inversion methods to deduce gross aerosol content and distribution within the atmosphere. A color photograph will be taken of each area by the observation telescope camera boresighted to the polarimeter.

1.2.2.13 Sferics Detector. Ground-based studies of sferics indicate that convective clouds may radiate radio noise other than the lightning-associated sferics, and that the noise may occur well before the cloud enters the lightning-producing stage. Also, the frequency with which such noise bursts occur appears to be related to the rate of vertical development of the cloud. The objectives of the sferics measurements are mapping the global distribution of thunderstorm activity, helping to identify weather features, and testing the theory that there are in progress at any one time some 1800 thunderstorms on Earth and that they maintain the Earth-ionosphere potential difference. The sensor consists of three modules: an antenna, a low-noise UHF receiver

direction of an on-board computer when supplied with target coordinates. A telescope system configuration (shown in Figure 1-3) consists of a low-power unit with a $\pi/6$ rad (30 deg) field of view (FOV) for acquiring targets and a high-power unit with a 7 mrad (0.4 deg) FOV for detailed examination of targets.

The low-power telescope is directly below the binocular eyepiece shown at the left side of the figure. The high-power telescope is the short assembly to the right, and includes a gimballed mirror for tracking targets with the 7 mrad (0.4 deg) FOV unit.

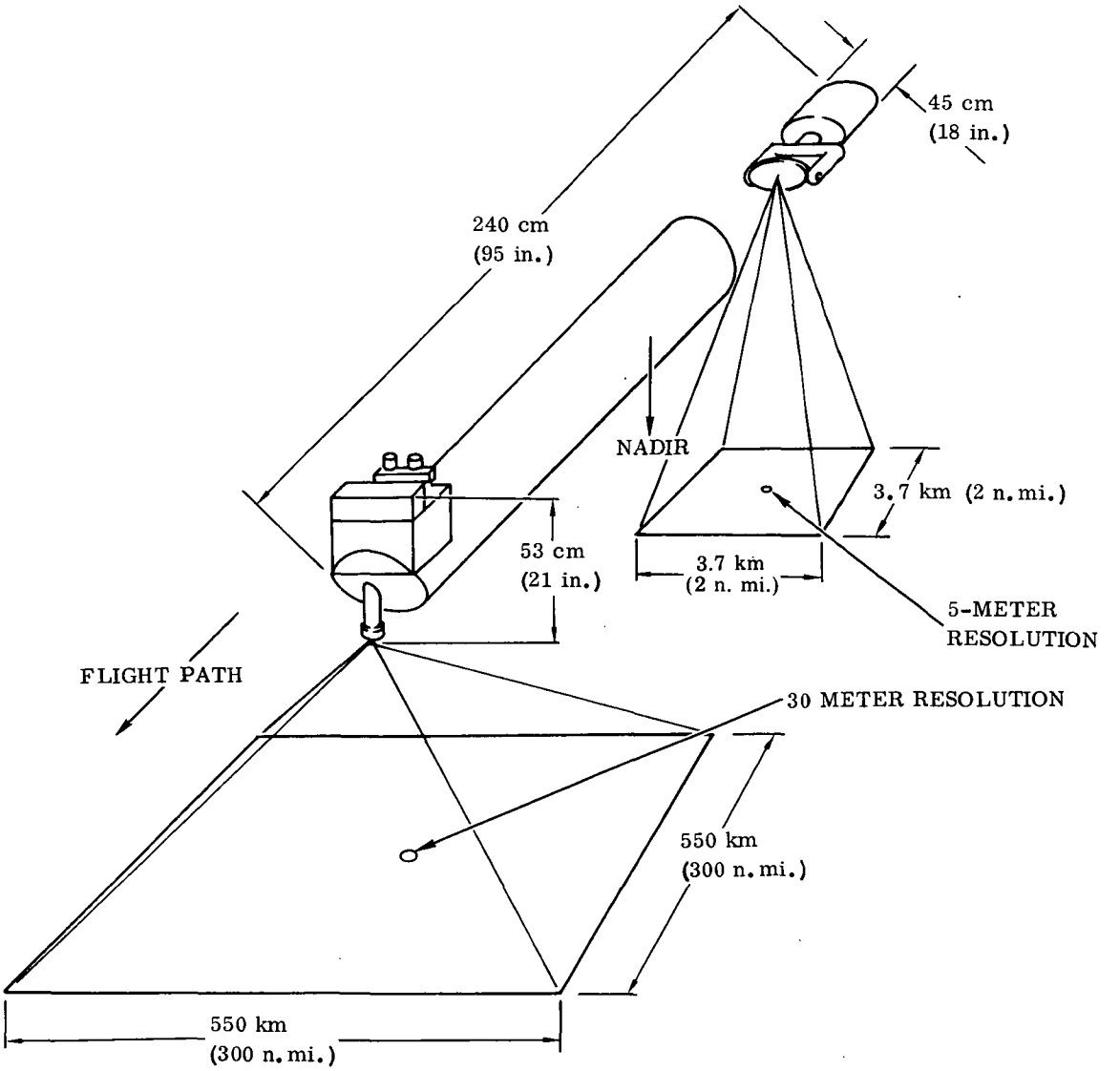


Figure 1-3. Observation Telescope System

The ability to observe targets located up to 0.874 rad (50 deg) forward, 0.7 rad (40 deg) aft and 0.786 rad (45 deg) across track is needed. Included in the assembly is a 35-mm camera to make a pictorial record of the scene. The telescope system will weigh about 112 kg (250 lb) without an associated computer and about 180 kg (400 lb) with it. The total power requirement is 540 watts.

The design of the telescope consists of a splitting mirror in the optics train ahead of the observation telescope eyepiece to allow insertion of a 35-mm film or television camera and an infrared spectrometer. The crew can view the scene at the same time that the data are being obtained by the camera and spectrometer. Other sensors will be mounted on a gimballed platform, which will be slaved to the telescope.

1.2.2.18 Data Collection. The initial Data Collection System probably will be patterned after that of the Earth Resources Technology Satellite System (ERTS). It is a system wherein data from ground-based sensors are transmitted to a spacecraft in bursts under control of a self-contained timer without benefit of an interrogation signal from the orbiting spacecraft. Examples of Earth observation measurements which might be collected by the platforms include seismic events, river flow rates, precipitation records, soil temperatures, wind velocities, and times of occurrence of various events. The Data Collection System will be designed to accommodate about 1000 collection platforms deployed throughout the world. A standard message consisting of 256 bits per transmission has been proposed; it will include provisions for all punctuation, timing, identification, and error encoding. Multiple transmission of standard messages can be used to handle larger quantities of data. For the type of Data Collection System proposed, the spacecraft must be ready to receive collected data at any time that a Data Collection Platform is in view. The spacecraft telemetry system will be used for transmission of the data received from the platforms to a ground data collection station. A data storage capacity equivalent to about 50 kilobits of digital data will be necessary.

1.2.2.19 Cloud Chamber. The cloud chamber is used to perform experiments in cloud physics in a precisely regulated and near-zero-gravity environment. For some time, experiments aimed at obtaining a better understanding of the cloud physics processes have been conducted in ground-based wind tunnels, cloud chimneys, and cloud chambers. However, they have been less than satisfactory because of the need to suspend the drop or crystal on a surface or holder (thus introducing a disturbance not present in nature), or alternatively to suspend the particle at terminal velocity in a vertical wind tunnel. A nearly zero-g environment would permit cloud elements to be suspended for long periods without danger of movement from convection and without the need for a solid support that destroys the relevance of the observation to the real environment. Because of the complexity of conducting these experiments, the manipulative skills of a scientifically trained astronaut are an advantage. Observations would be made by the onboard investigator with the unaided eye and a microscope. Still pictures and high-speed and time-lapse motion pictures of events in the cloud chamber, as seen through the microscope, also would be made.

1.2.2.20 Controls and Displays. Sensors that output in analog or digital format will be monitored with CRT scopes and displays. The CRT displays will be the moving display type and the scopes should be of a type that permits the crew to monitor the full voltage range of the scene. A multichannel oscilloscope will be incorporated in the display panel and be computer driven. The system should have sufficient buffer storage so that scene redundancy can be analyzed and only spectral differences displayed in the multichannel unit.

At least one, and possibly two, analytical display units should be employed. Hardware and software have been developed with a color output display and have been used on both visible and microwave data analysis. Both displays are computer driven since there is a requirement for the multifrequency data to be reformatted, registered, buffer-stored and analyzed. The computer should have sufficient core to handle the normal cross-correlation, thresholding and clipping, as well as second- and third-order statistical-analysis algorithms presently in use because it also will be used in data analysis.

There is also a requirement for the telescope drive-train assembly to be computer controlled. It is necessary to process the pointing and tracking data in parallel with vehicle location data to determine the latitude and longitude of the terrain feature acquired by the telescope.

The controls and displays will require about 0.7 m^3 (25 ft^3), weigh 360 kg (800 lb), and consume an average power of 1200 watts. The telescope computer is estimated to weigh an additional 67 kg (150 lb).

The principal Control and Display devices for the various elements of the experimental program are summarized in Table 1-3.

The first column of the table lists typical types and numbers of control devices. Position controls are used for controlling diffraction gratings, apertures, filters, airlock extenders, and similar items. Sequence controls are used for timing and command functions. The level and sensor controls permit selecting any one of a number of similar sensors for readout on a common display.

The second column identifies the display devices and the numbers required. Mode indicators are essentially indicator lights for on/off or auto/manual type indications. Digital readout displays are used for exposure time controls, frame rate controls, etc. The selection indicators are used to convey information on sequence control, focus and alignment, data monitor selection, sensor selection, antenna orientation, EC/LS, heater control, and level controls. Video displays are intended as imagery devices, but are not exclusively limited to this use. CRT displays are intended for both alpha-numeric data and for triggered sweep displays.

Table 1-3. Control and Display Devices

Control Devices	Number	Display Devices	Number
Level Control	1	CRT or Similar	6
Antenna Orientation	3	TM Data Display	6
Sensor Selector	19	Position Indicator	4
Frame Rate	2	Selection Indicator	20
Sequence/Command Controls	6	Digital Readout	8
Pointing Control	2	Video	2
Pitch, Roll and Yaw	6	Mode Indicator	26
On/Off	20		
Position Controls	14		

1.2.2.21 Data Analysis Equipment. Sufficient data processing and analysis equipment should be carried onboard to permit a substantial involvement of the crew in data selection, management and first-order analysis. Many of the displays described under Controls and Displays also will be used for data analysis. In addition, a capability for 35, 70, and 240-mm film processing should be provided. The total equipment is estimated at 608 kg (1335 lb), 870 watts of power, and will occupy a volume of about 1 m^3 (40 ft^3).

The data reduction area is estimated to require 7 m^2 (75 ft^2) and consist, typically, of the following items of equipment:

	Weight (kg)	(lb)
1 double console (includes equipment)	90	200
Digital tape transport	45	100
Computer keyboard and stand	32	70
Straight-edge and plotter table	13	30
Lightboard and microscope plotting aid equipment	14	75
Tape storage cabinets	22	50
Electronic racks (includes equipment)	63	140
	299	665

The photo development area requirement is estimated at 5.5 m^2 (60 ft^2) and will contain the following typical equipment:

	Weight (kg)	(lb)
Work table	34	75
Storage cabinet	34	75
Chemical storage cabinets	22	50
Consumables	90	200
Photo file cabinets	34	75
Slide and movie projectors	18	40
Viewing screen	2	5
Processor	68	150
	302	670

1.2.2.22 Maintenance and Repair. Typical electronic laboratory equipment for maintenance, repair, modification, and calibration are the following. About 3m^2 (100 ft^2) of floor space are required.

	Weight (kg)	(lb)
Work bench	56	125
Storage cabinet	56	125
Wall tool rack and tools	79	175
Test equipment, e.g., MFM oscilloscope, power supplies	67	150
	258	575

1.2.3 DATA REQUIREMENTS. Table 1-2 lists the data outputs of each of the sensors discussed in the preceding section. Camera and radar outputs are on film and all others on 25 mm (1 in), multitrack magnetic tape, although a data system designer may prefer to put a very high data rate sensor, such as the Multispectral Scanner, on digital film. The column titled "Generation Rate" shows the data rate for each sensor of a multisensor set or for each channel for a multichannel sensor. The coding listed does not include data formatting requirements. The rate (cm/min) of camera film assumes a 0.96 rad (55 deg) overlap of successive frames.

The next column gives the number of individual cameras in a typical camera assembly and the number of individual data channels in a typical multichannel sensor. The total bits per second generated by all channels of the multichannel sensors is listed next. Single polarization is assumed for all microwave sensors. Packing densities used in computing the length of film or tape are as follows:

Media	Packing Density	Remarks
Camera film	35 LP/mm	Overall optics-film system resolution
25 mm (1 in) magnetic tape	1×10^6 bits/2.54 cm	Requires advanced recording techniques or use of 70-mm digital film

1.3 REQUIREMENTS SUMMARY

The principal requirements of the seven experiment areas are summarized in Table 1-4 and discussed in detail in Section 1.4. Both sensor requirements and support facility (items 16-21 of Table 1-2) requirements are tabulated. The Data Analysis and the Maintenance and Repair support facilities support all of the experimental areas. As discussed in Section 1.2.2.21, the Data Analysis facility consists of a data review and analysis section and a photo development section. The photo section may not be used in all experimental areas, e.g., Ocean Resources.

The weight, volume, power and orbital entries are for a payload consisting of the sensors required to do all of the experiments of a particular experiment area. In order to specify realistic data requirements, however, an experiment duration must be selected. A representative or model experiment was developed for each area, and the durations of these representative experiments are listed in the column titled "experiment time limits." The number of minutes per data-taking pass is an average, since geography and Sun angle cause the actual duration to vary from pass to pass.

Crew skills listed in the table are those that are unique to the particular experimental area. Electrical, mechanical and optical technical skills are also required, and they are listed under Controls and Data Analysis because these skills are common to all experiments.

Each experiment area uses a number of sensors, so the overall environment and stability requirements of most areas is the same. The stability requirement of 0.175 mrad (0.01 deg)/sec in Area I is due to the aeronomy spectrometer. If this sensor is not used the requirement becomes 0.874 mrad (0.05 deg)/sec, as with the others. The first entry under orbital data is the preferred and the second altitude is acceptable. Any orbit inclination is acceptable as long as its maximum latitude is that entered here.

Table 1-4. Experiment Requirements Summary

EXPERIMENT AREA	ITEM	WEIGHT kg (lb)	VOLUME m^3 (ft^3)	ENVELOPE (ft)	TOTAL POWER REQUIREMENTS (watts)	CREW SKILLS UNIQUE TO EXPERIMENT	ENVIRONMENT REQUIREMENTS	REPRESENTATIVE EXPERIMENT TIME LIMITS	DATA REQUIREMENTS	STABILITY AND CONTROL	ORBITAL DATA
I. Weather and the Atmosphere	7 General Sensors 2 Experimental Sensors	905 (2000)	18.3 (640)	See Tables 1-2 and 1-5	s.b. 844 avg. 3404 pk. 4326	Meteorologist Oceanographer	• Minimal thruster operation while optical surfaces are uncovered. • Clean class: 100,000 • Film storage: 280-300°K (50-90°F) 30-70% relative humidity 0.9 rad/day	7 days, 14 passes, 15 min per pass	Rate: 124 kbs Wt.: 23 kg (51 lb) Vol.: 0.013m^3 (0.44 ft^3)	Pointing: ±8.74 mrad (±0.5 deg) Rate: 0.175 mrad (0.01 deg)/sec	• Altitude 185-500 km (100-270 nmi) • Inclination 50-90 deg
	Support Equipment	929 (2065)	2.4 (84)								
II World-Land Use Mapping	8 General Sensors 1 Experimental Sensor	1169 (2588)	8.23 (325)	See Tables 1-2 and 1-6	s.b. 663 avg. 4135 pk. 5100	Cartographer Geographer Physical Geologist		5 days, 11 passes 25 min per pass	Rate: 50.1 Mbs Wt.: 127 kg (398 lb) Vol.: 0.068m^3 (2.42 ft^3)	Pointing: ±8.74 mrad (±0.5 deg) Rate: 0.874 mrad (0.05 deg)/sec	
	Support Equipment	539 (1200)	1.0 (37)								
III Air and Water Pollution	6 General Sensors 2 Experimental Sensors	850 (1885)	7.74 (272)	See Tables 1-2 and 1-7	s.b. 401 avg. 3038 pk. 3826	Meteorologist Hydrologist Oceanographer		4 days, 20 passes 12 min per pass	Rate: 3800 bits/sec Wt.: 22 kg (50 lb) Vol.: 0.009 m^3 (0.33 ft^3)	Pointing: ±8.74 mrad (±0.5 deg) Rate: 0.874 mrad (0.05 deg)/sec	
	Support Equipment	544 (1211)	1.1 (38)								
IV Resource Recognition and Identification	7 General Sensors 2 Special Sensors	1109 (2455)	7.96 (317)	See Tables 1-2 and 1-8	s.b. 616 avg. 4008 pk. 4826	Agronomist Geologist		3 days, 9 passes 15 min per pass	Rate: 50 Mbs Wt.: 32 kg (70 lb) Vol.: 0.013m^3 (0.45 ft^3)	Pointing: ±8.74 mrad (±0.5 deg) Rate: 0.874 mrad (0.05 deg)/sec	
	Support Equipment	477 (1061)	1.05 (34)								
V Disaster Assessment	7 General Sensors 1 Special Sensor	1191 (2412)	13.25 (516)	See Tables 1-2 and 1-9	s.b. 505 avg. 2436 pk. 3196	Meteorologist Geologist Agronomist Hydrologist		7 days, 10 passes 3 min per pass	Rate: 51.4 Mbs Wt.: 25 kg (56 lb) Vol.: 0.010m^3 (0.36 ft^3)	Pointing: ±8.74 mrad (±0.5 deg) Rate: 0.874 mrad (0.05 deg)/sec	
	Support Equipment	544 (1211)	0.71 (26)								
VI Ocean Resources	5 General Sensors	737 (1623)	13.17 (476)	See Tables 1-2 and 1-10	s.b. 331 avg. 2601 pk. 3078	Oceanographer Meteorologist		7 days, 28 passes 15 min per pass	Rate: 51.3 Mbs Wt.: 165 kg (367 lb) Vol.: 0.08 m^3 (2.68 ft^3)	Pointing: ±8.74 mrad (±0.05 deg) Rate: 0.874 mrad (0.05 deg)/sec	
	Support Equipment	365 (811)	1.2 (40)								
VIII Special Research	TBD							TBD			
SUPPORT FACILITIES											
Data Analysis	Data Analysis Photo Development	299 (665) 302 (670)	40		s.b. 50 avg. 900 pk. 900	Photo Technician Cartographer					
Maintenance and Repair	Tools and Instruments	258 (575)	20		avg. 50 pk. 300	Electromechanical Tech. Optical Tech.					

Figure 1-4 shows the spectral range of each experiment area except Area VII, Special Research. Each area covers a sizable spectral range and man will be of value in selecting the best part of the range for a particular experiment at a particular time. The three-decade range of Area I, Weather and the Atmosphere, is provided by the aeronomy spectrometer sensor.

1.4 EXPERIMENT PROGRAM

Seven experiment areas have been selected as typical of those in which research might be done aboard the Earth Observations Facility. The purpose in defining representative experimental areas is to develop some realistic estimates of the number of sensors, volume of data, amount of power, number of crew skills, etc., that a facility might require. Realistic estimates also are needed for sizing the power, communication, life support and consumables interfaces between the facility and the space vehicle.

The principal source of these experiment areas was the Earth Orbital Experiment Program and Requirements Study of the NASA Langley Research Center. Each area includes a number of research clusters from the study that have common objectives and/or observation techniques, sensors, user applications, etc. The areas also include suggestions for experiments offered by members of the Earth resources remote-sensing community in Government, universities and industry:

a. Area I, Meteorology and the Atmospheric Sciences

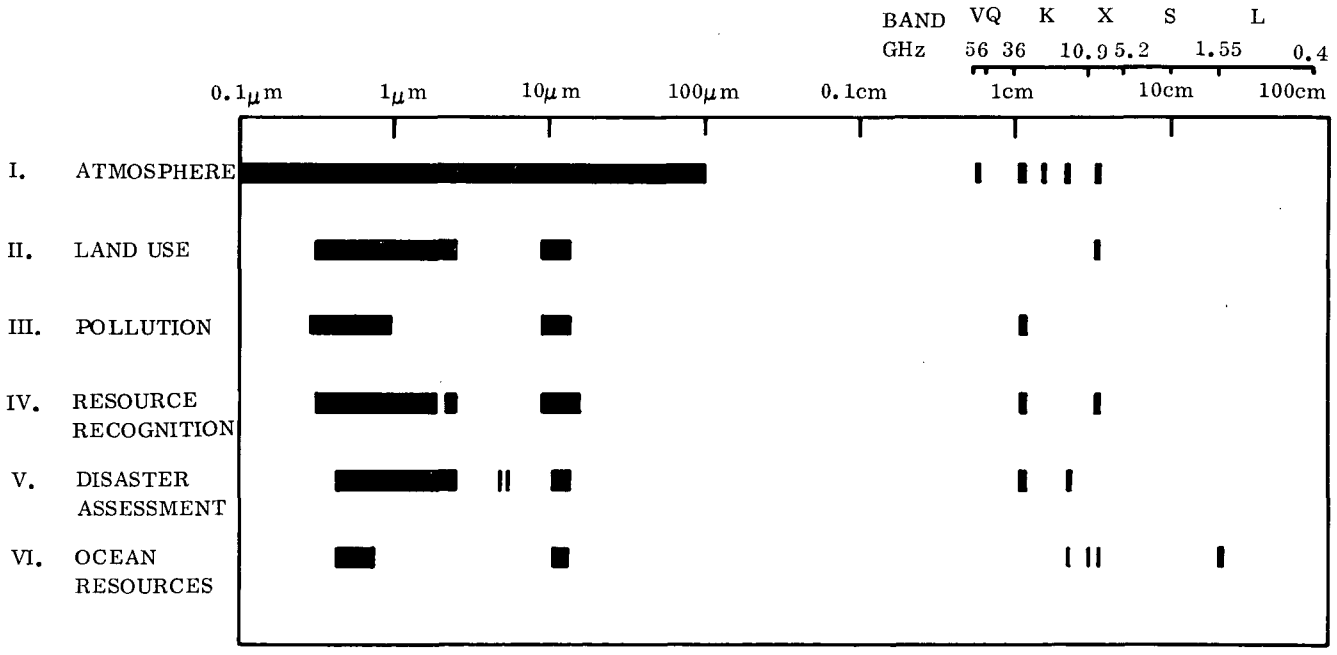


Figure 1-4. Spectral Range of Experiment Areas

b. Area II, World Land Use Mapping

c. Area III, Air and Water Pollution

d. Area IV, Resource Recognition and Identification

e. Area V, Natural Disaster Assessment and Anomalies

f. Area VI, Ocean Resources

g. Area VII, Special Research.

Experiment Area I includes weather and atmosphere-oriented experiments in cloud physics, in support of special meteorology experiments such as GARP, and in effects of the atmospheric transmission on observations of objects on the surface. Area II includes experiments of an inventory or mapping nature, e.g., urban vs. rural land uses, size and location of lakes and rivers, extent of snow, ice, etc. Area III includes experiments concerned with the source and degree of pollution of the atmosphere, land, and water. All experiments having to do with the location, recognition or identification of resources fall into Area IV; examples are mineral discovery and crop species identification. Natural disasters, such as floods or wildfires, that require a routine patrol to keep a lookout, followed by intensive observation of a small area once a disaster has occurred, are covered in Area V; the sensors and observation techniques also are amenable to discovering thermal anomalies (for example, geothermal energy sources), and these also are included here. Oceanographic research on currents, sea temperature, fisheries, and the like are covered in Area VI. Area VII includes all observations and measurements that are too developmental in nature to fall logically in any of the specific areas.

To provide realistic estimates of the amount of data that will be generated and of energy that will be required, one or two representative experiments have been defined in each experimental area. The Experiment Time Limits and the Data Requirements columns of Table 1-4 require that an experiment duration be selected. Duration of these representative experiments in each Experiment Area was used to develop the entries for these columns.

An attempt was made to provide a variety of experiments to determine those types of experiments that will be design drivers. For example, some experiments involve large area targets and others widely separated point targets. A distinguishing feature of each representative experiment is listed below.

Experiment Area	Unique Characteristic of Representative Experiment
I	Moderate data rate but moderate duration
II	Longest overland sweep

Experiment Area	Unique Characteristic of Representative Experiment
III	Small data rate but long duration
IV	Large data rate but short duration
V	Widely scattered small targets
VI	Longest overwater sweep

Until a sensor or recognition technique is proved-out, most of the observations will be made over test sites. The orbit inclination should be great enough to cover the multi-disciplinary test sites indicated by the shaded areas on Figure 1-5 and listed opposite. The large dots on the map are NASA Earth Resources Aircraft Program test sites. Geography pilot project sites of the Department of the Interior are included also.

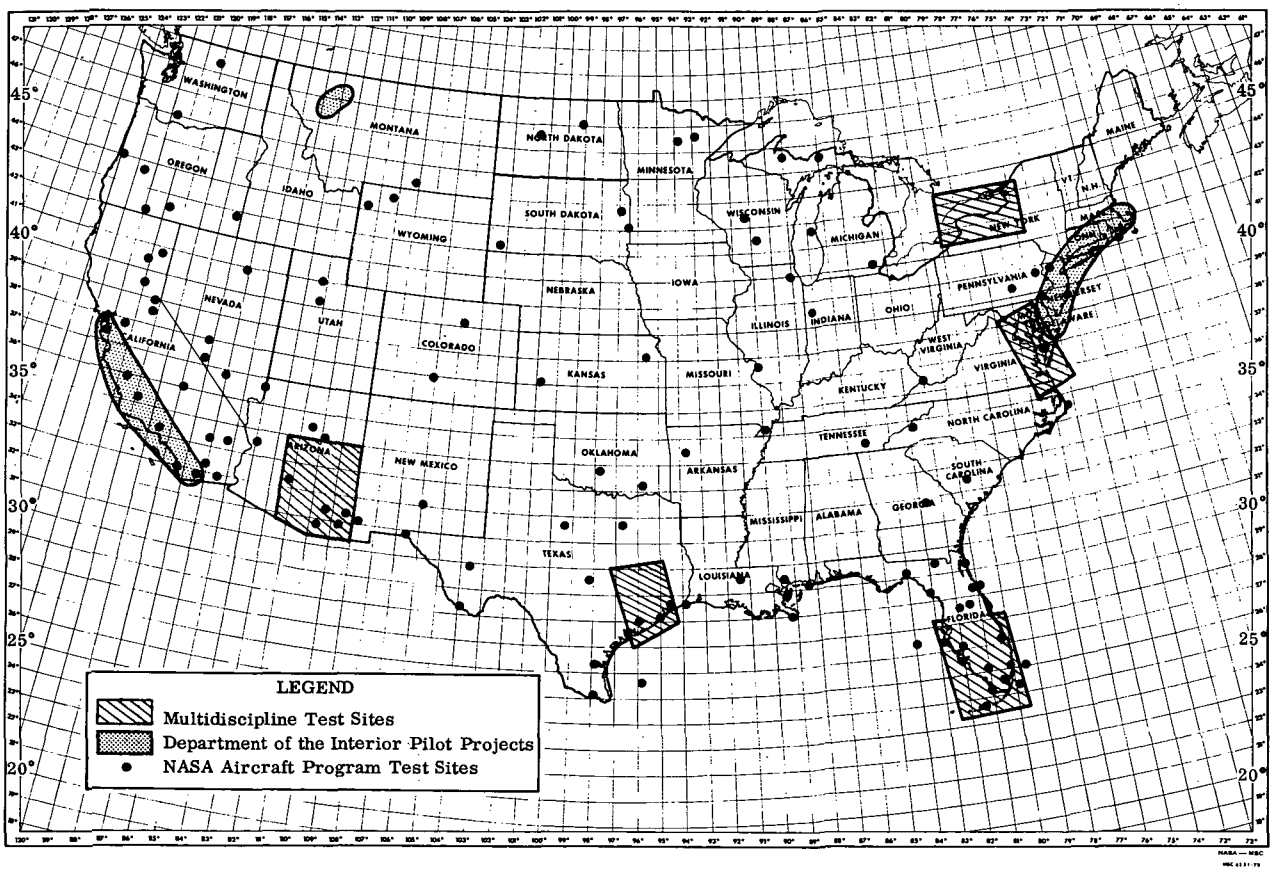


Figure 1-5. Test Sites in the United States

Sites		
Chesapeake Bay	Hydrology	Estaurine and coastal hydrology
	Geography	Urban change detection
	Resources Mgmt.	
Lake Ontario	Hydrology	Water quality parameters
	Geography	Urban change detection
	Resources Mgmt	
South Florida	Hydrology	Water quality parameters
	Oceanography	Sea color and penetration
	Agriculture	Crop identification and inventory
	Geography	Urban change detection
Phoenix, Arizona	Agriculture	Crop identification (land use, range-land)
	Geography	Urban change detection
	Hydrology	Inland hydrologic features
	Geology	
	Resources Mgmt	
Houston, Texas		

A land-use type of experiment requires seasonal to yearly coverage to observe changes in planting and growth patterns of crops. A five-year frequency is satisfactory for slowly changing uses, such as forest. Geographers have suggested a ten-year interval for urban land use to coincide with the Federal census. At the other extreme is disaster assessment where daily to monthly overflight is required to assess damage and plan relief or to keep an eye on a suspected precursor of a disaster.

1.4.1 AREA I, METEOROLOGY AND THE ATMOSPHERIC SCIENCES

1.4.1.1 Scientific or Technical Objective. The objective of this experiment area is to provide intensive and concentrated observational support from space to meteorology

and the atmospheric sciences. This area also will develop data on profiles of atmospheric pressure, temperature and water vapor of the homosphere, and the chemical and electrical composition of the chemosphere and ionosphere. An objective of particular importance to remote sensing is research on the effects of atmosphere transparency, inversion layers, solar illumination, slant range, and cloud cover on the signatures and appearance of Earth resources when observed from space.

1.4.1.2 Description. Three experiments have been selected as representative of the area:

a. Support of the Global Atmospheric Research Program (GARP).

b. Atmospheric effects on the signatures of surface phenomena.

c. Cloud physics research in a zero-gravity cloud chamber.

The GARP will conduct experiments on tropical cloud clusters and for the global observing system Atlantic test. The Earth Observations Facility will support these experiments by making high resolution (spectral and spatial) measurements of atmospheric radiation originating at the land and ocean surfaces, cloud tops, and within the atmosphere. These space-based measurements will be made in concert with surface-based measurements and together they will be used to derive temperature and water vapor profiles, and surface and cloud-top temperatures. In addition, a measure of thermal convective activity in both thunderstorm and non-thunderstorm clouds will be obtained using UHF sferics instrumentation. High-resolution cloud photography will be obtained by a metric camera for correlation with the radiometric and sferics data, as well as for general meteorological referencing and research studies. The duration of these experiments is relatively long, since the GARP special area extends 20 degrees on either side of the equator, and the entire length will be observed on each data pass.

Atmospherics effects experiments will be done over ground truth sites with ground targets of known and controlled characteristics. Extensive measurements of the surface and upper-atmosphere meteorological properties, solar illumination, etc., will be made both at the test site and from space. These experiments are of short duration because the targets are relatively small, but the measurements must be precise.

A cloud chamber operating in the zero gravity of space will be used for onboard research in cloud physics with emphasis on weather modification. A zero-g environment will permit cloud elements to be suspended for long periods without danger of movement from convection and without the need for a solid support that destroys the relevance of the observation to the real environment. Because of the complexity of conducting these experiments, the manipulative skills of a scientifically trained astronaut are an advantage.

1.4.1.3 Observation/Measurement Program

1.4.1.3.1 Location. Observations in support of Special Area Studies, e.g., GARP, will be concentrated in the portion of the Atlantic between ±20 degrees latitude that is shaded in Figure 1-6. Measurements of the effects of the atmosphere on resource signatures and characteristics will be done at the test sites located in the United States in Figure 1-5. Adequate ground and aircraft instrumentation should be available at the sites to measure the atmospheric pressure, temperature, transparency, etc. A possible procedure would be to make GARP measurements during the two descending trajectories shown passing over the Atlantic in Figure 1-6, using GARP ships for ground truth for oceanic observations. The early part of the second orbit crosses the Lake Ontario multidiscipline test site and the third orbit passes near the Southern Florida site, and the atmospheric effects measurements can be made using the sites. Cloud physics research could be done at any time.

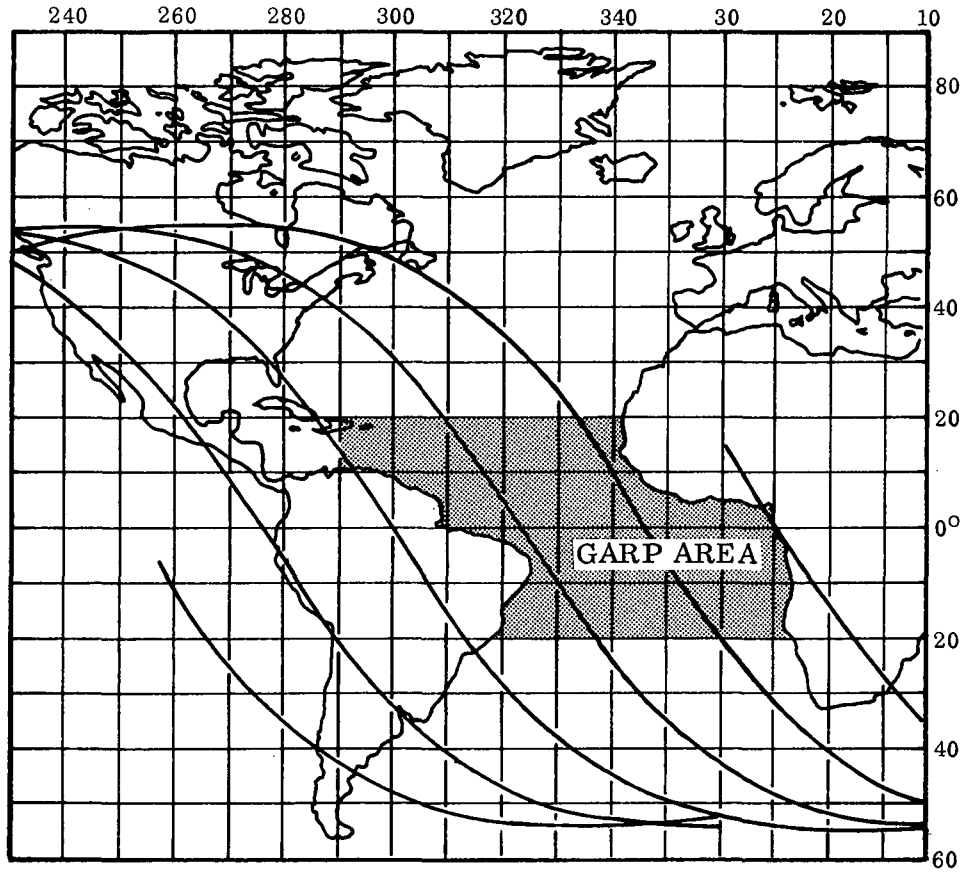


Figure 1-6. Ground Tracks for GARP Support Equipment (Orbit Altitude 456 km (246 n. mi.); Inclination 55 deg)

1.4.1.3.2 Observables. Radiance measurements made with ultraviolet, visible, infrared and microwave radiometers and spectrometers will be inverted by the user into profiles of temperature, water vapor, ozone, carbon monoxide, etc. Polariometer data will indicate the aerosol content of the atmosphere. The sferics and microwave scanner data will locate areas of electrical storms, severe convection, and rain. Polarized surface roughness data from the microwave radiometer/scatterometer/altimeter will yield information on the effect of surface roughness on the intensity and polarization of upwelling radiation.

A single metric camera will photograph the scene at appropriate intervals to provide a record of the local terrain, cloud cover, and gross atmospheric transparency. Space vehicle position, attitude and sensor operation status must be provided together with visual and photographic observations acquired by unmanned meteorological satellites, aircraft, surface stations, balloons, radiosondes, etc.

For the cloud chamber experiments, the data should include voice-recorded eye and microscope observations of suspended water droplets and crystals, and film-recorded (individual pictures, high-speed and time-lapse photography) events in the cloud chamber taken through the microscope. Strip-chart records of chamber environment, such as temperature, pressure, dewpoint, electrical field, ionization, and composition also are required.

1.4.1.3.3 Sensors. The principal sensors for the experiments in this area are listed in Table 1-5, along with the volume, weight, and power requirements. The aeronomy spectrometer, for measurements of atmospheric chemical and physical properties, is slaved to the observation telescope so the astronaut can select targets and train the spectrometer assembly. The multispectral infrared radiometer is carried for surface and atmospheric temperature measurements.

The multifrequency microwave radiometer is used in studies of cloud density and rainfall intensity and distribution. The microwave radiometer/scatterometer/altimeter will be used for sea surface roughness measurements. The multispectral spectrometer and polarimeter are included primarily for the atmospheric effects experiment. The IR radiometers also should be slaved to the telescope.

1.4.1.4 Interface, Support and Performance Requirements

1.4.1.4.1 Data. Data amounts listed below are for the representative GARP support experiment. The assumed location and ground tracks are shown on Figure 1-6. The actual duration of a data run depends upon orbit inclination, illumination, closed cover and such, but 15 minutes per data pass, 2 passes a day and a 7-day long experiment were taken as representative. Data consists of both photographic film and magnetic tape.

Table 1-5. Instrumentation and Observation Requirements for Area I, Meteorology and Atmospheric Sciences

Sensors	Weight (kg)	Weight (lb)	Volume (m^3)	Volume (ft^3)	Power Aver(W)	Power Pk(W)
1. Metric Camera	250	550	1.2	42	500	780
5. Microwave Scanner	114	250	5.6	197	175	175
7. Multispectral Radiometer	18	40	.1	2	20	20
8. Microwave Radiometer	200	450	9.4	330	160	160
9. Scatterometer	74	163	.3	10	153	300
10. MS Spectrometer	160	350	.2	6	170	250
11. Aero Spectrometer	61	136	1.3	47	260	650
12. Polarimeter	18	40	.1	3	20	45
13. Sferic Detector	10	22	.1	3	6	6
Total	905	2001	18.3	640	1464	2386
16.) 17.) Telescope and Computer	179	400	.3	12	540	540
19. Cloud Chamber	90	200	.8	27	200	200
20. Controls and Displays	360	800	.7	25	1200	1200
Total	629	1400	1.8	64	1940	1940
21. Data Analysis (Electronic Only)	300	665	.6	20	400	400
22. Maintenance and Repair	258	575	.6	20	258	575
Total	558	1240	1.2	40	450	700

Observation Requirements

Season		All
Frequency		3 per week
Sun Elevation	Pref.	60 degrees
	Accept	*
Cloud Cover	Pref.	20 percent
	Accept	*
Orbit Altitude	Pref.	185 km (100 n mi)
	Accept	*
Latitude	Pref.	90 degrees
	Accept	50 degrees
Pointing		+0.5 degrees
Attitude Rate		0.05 deg/sec

*See Section 1.4.1.4

Maximum tape-recorded data rate	125 kbs
Total data weight	23.5 kg (51.5 lb)
Total data volume	0.01 m^3 (0.44 ft^3)

Atmospheric Effects Experiment data generally will be taken at the point of closest approach to the test site. The data from a single pass will consist of 15 seconds of operation by the sensors as the site passes through the field of view, and 12 minutes of telescope operation during the entire orbit to acquire test sites, evaluate cloud cover, point and track the sensors, etc. It is assumed that, on the average, three test sites or areas can be viewed on a single data pass. Daily quantities for the three 15-second passes per day of the Atmospheric Effects experiment using sensors 5, 7, 8, 10, 11, 12, and 16 are indicated below:

	Length		Weight	
	(cm)	(ft)	(kg)	(lb)
240 mm (9-1/2 in) film	72	2.4	0.019	0.042
70 mm film	42	1.4	0.009	0.021
25 mm (1 in) tape	1520	51	0.072	0.159

Results of the cloud chamber visual observations and the environment measurements will be recorded on magnetic tape at an assumed rate of 15.25 cm (0.5 ft)/min. Cloud drop size data will be filmed on 35 mm motion picture film. The experiment duration is not yet determined.

1.4.1.4.2 Power. The power requirements of each item of equipment are listed in Table 1-5. Sensor power requirements for the three representative experiments are as follows:

Experiment	Duration (min)	Average (W)	Peak (W)	Energy (kW-min)
GARP Support	210	1464	2386	310
Atmospheric Effects	1.5	1285	2060	2
Cloud Chamber	TBD	200	200	TBD

For the GARP Support experiment all nine sensors listed in Table 1-5, the telescope, and the controls and displays unit are used. The atmospheric effects experiment does not require the microwave, sferics, nor scatterometer sensors. Power levels for the controls and display and data analysis units are listed separately.

Energy consumption is tabulated above. It is assumed that the GARP Support experiment is two 15-min periods each day and the Atmospheric Effects experiment is six test-site passes each day.

1.4.1.4.3 Orbit. Orbit altitude and inclination requirements for the GARP Support experiment, listed in Table 1-5, are representative of the entire Experiment Area I. The ideal altitude for the GARP experiment is a stationary position directly over the area. At present, these areas tend to be in the lower latitudes, so a low inclination is satisfactory. However, if an arctic area research program is undertaken in the future, a polar orbit will be required. A 50-degree inclination is satisfactory for Atmospheric Effects experiments since almost all test sites are south of 50 degrees. Cloud physics experiments have no significant orbit requirements.

Weather and Atmospheric Effects experiments will be made in all seasons, and the frequency with which they are made will be set by the requirements of the special area studies they are supporting. Atmospheric Effects observations should be made at least daily, and it might prove wise to make them hourly during the season in which the resource is normally observed, e.g., in spring for snow melt.

The Special Areas Support experiment has no requirements for solar illumination or cloud cover, since the observations are largely of the atmosphere itself and not of the surface. The Atmospheric Effects experiment requires observation of surface targets and prefers a high sun and scattered clouds. However, an objective of the experiment is to determine the effects of illumination level and cloud obscuration, so there will be times when cloud cover or a low illumination level is required.

The Special Areas experiment prefers a synchronous altitude over the special area being studied, and the areas tend to be in the tropics. However, a one-day repeatable 500km (270 n. mi.) orbit is acceptable. The Atmospheric Effects orbit should be as low as possible for the best surface resolution and the inclination high enough to include the multidisciplinary test sites shown in Figure 1-5.

1.4.1.5 Potential Role of Man. The role of man in setup, operation and maintenance is discussed in Section 1.7. Special skills that would be useful are meteorological and oceanographical. The GARP Special Areas experiment is a mapping type experiment and requires little tracking with the observation telescope. On the other hand, the Atmospheric Effects experiment requires that a test site be acquired and tracked with the telescope for at least a half-minute. The data will be examined for electronic quality and experimental usefulness and direct verbal communication with fellow experimenters on the ground is required. The Cloud Chamber experiment can be directed by a meteorologist who is a specialist in cloud physics and assisted by an electro-optical technician.

1.4.1.6 Available Background Data. The sources of background data are listed in Section 1.11.

1.4.2 AREA II, LAND USE MAPPING

1.4.2.1 Objective. This experiment area will collect cartographic data for use in increasing the coverage of worldwide thematic and land use maps and to upgrade present maps. In addition, data will be gathered for the production and refinement of surface geotectonic maps. The location and areal extent of major lakes, reservoirs, rivers, snow cover and ice pack will be recorded. The shape, size, and drainage patterns of seas, lakes, and river systems will be determined.

Applicable sensors and sensing techniques will be assessed under variable illumination, atmospheric transparency, and cloud cover conditions. Ground truth keys or signatures for valid interpretation of remotely sensed data will be studied for their application to geographical regions where little or no ground truth information is available.

1.4.2.2 Description. The representative experiment selected for this area is research in determining gross land use from space. Observations will be made that will enable the geographer to identify and assess urban, rural and primitive land uses. Much of the sensor and analysis technology already exists, since gross land use mapping has been done from aerial photography since the 1930's. Research here will attempt to adapt airplane techniques to space and to use sensors and sensing techniques that, possibly, have not been exploited heretofore. Being a mapping experiment, the areas observed will tend to be large, and the experiment duration relatively long. The large-size multidiscipline test sites, rather than small single targets, will be used for system calibration and signature research, but this particular type of mapping experiment is less tied to test sites than most. High spatial resolution and precise pointing generally are not required, since it is gross land use, not species identification, that is sought. Illumination and geographical restrictions probably will restrict the data gathering to from one-sixth to one-third or an orbit. The balance of the orbit can be used for handling, processing, and analysis of samples of data in preparation for the next run.

1.4.2.3 Observation/Measurement Program. Observations and measurements can be made throughout the world; however, initially they will be concentrated on the Western Hemisphere where ground truth is available more readily.

The representative mapping experiment for this experiment area has been sized using a five-day period, the ground traces for the first and fifth day of which are shown in Figure 1-7. This five-day set of orbits was selected because they cover the major part of the Western Hemisphere during daylight. Orbits 291 and 292 of Day 1 can be used to map the Maritime Provinces and the fisheries of the Grand Banks. Orbit 293

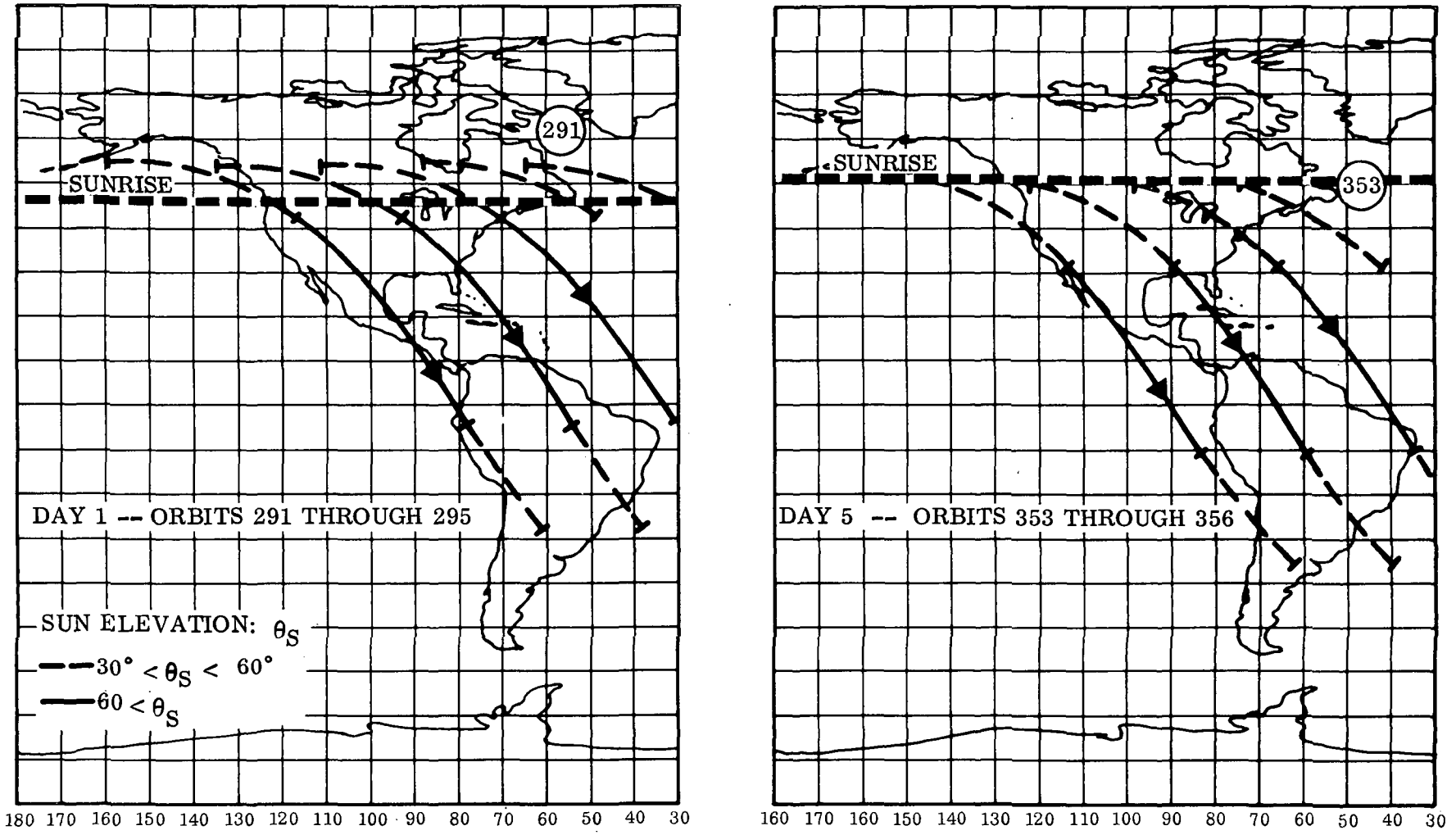


Figure 1-7. Ground Tracks for Land Use Mapping

sweeps over the wheat and corn belt of the plains, over the Caribbean Sea, and then across Brazil. Orbit 295 passes over the fisheries in the Gulf of Alaska and then the entire length of North, Central, and South America. The dashed portion of the ground trace is where the solar elevation is $\pi/6$ rad (30 deg) or greater, and the solid portion is where the illumination is $\pi/3$ rad (60 deg) or greater.

1.4.2.3.1 Observables. Land use and thematic mapping is done by sensing from space the following phenomena:

a. Boundaries of fields, roads, rail lines, timberlines, etc.

b. Broad-band and narrow-band color differences of crops, trees, soil, buildings, artifacts, etc.

c. Topography, texture and roughness of terrain.

d. Areal extent of surface water, snow, ice and associated vegetation.

e. Temperature differences of terrain.

1.4.2.3.2 Sensors. The nine sensors listed in Table 1-6 will do all of the experiments proposed for the Land Use Mapping experiment area of the Langley Research Center Study. They all are useful to the representative experiment selected for the area, too, although the principal sensors are the five imaging sensors, because gross land use mapping traditionally relies on imagery. The polarimeter will be used as a reflectometer operating in the near ultraviolet and visible to view the surface and determine its texture and roughness by the amount and polarization of the energy it reflects. The spectrometer will detect narrowband spectral differences of rock, soil, vegetation, etc., and the radiometer will sense temperature differences between soil, water, snow, vegetation, etc.

1.4.2.4 Interface, Support and Performance Requirements

1.4.2.4.1 Data. The principal data recording media will be panchromatic and infrared photographic film of all types. These kinds of media are amenable to onboard photo evaluation and interpretation, so a photo unit will be part of the data analysis facility. The profiler sensors will be recorded on magnetic tape and the data facility will include provision for readout on CRTs, strip charts, or similar displays. Total data amounts for the five-day gross land use mapping experiment are as follows:

Maximum tape-recorded data rate	50.1 Mbs
Total data weight	179kg (398 lb)
Total data volume	0.068 m^3 (2.42 ft^3)

Table 1-6. Instrumentation and Observation Requirements for Experiment Area II, Land Use Mapping

Sensors	Weight (kg)	Weight (lb)	Volume (m^3)	Volume (ft^3)	Power Aver(W)	Power Pk(W)
1. Metric Camera	250	550	1.2	42	550	780
2. Multispectral Camera	265	590	.14	5	170	600
4. Multispectral Scanner	135	300	.6	21	190	190
5. Microwave Scanner	114	250	5.6	197	175	175
6. Microwave Radar	135	300	.12	41	1000	1000
7. Multispectral, Radiometer	18	40	.04	1	20	20
9. Scatterometer	74	163	.3	10	153	300
10. Multispectral Spectrometer	160	350	.17	6	167	250
12. Polarimeter	18	40	.06	2	20	45
Total	1169	2583	8.23	325	2395	3360
16. Telescope and 17. Computer	179	400	.3	12	540	540
20. Controls and Displays	360	800	.7	25	1200	1200
Total	539	1200	1.0	37	1740	1740
21. Data Analysis	608	1335	1.2	40	900	900
22. Maintenance and Repair	258	575	.6	20	50	300
Total	866	1910	1.8	60	950	1200

Observation Requirements

Season		All
Frequency		Seasonal
Sun Elevation	Pref.	60 degrees
	Accept	30 degrees
Cloud Cover	Pref.	20 percent
	Accept	50 percent
Orbit Altitude	Pref.	185 km (100 n mi)
	Accept	500 km (275 n mi)
Latitude	Pref.	70 degrees
	Accept	50 degrees
Pointing		±0.5 degrees
Attitude Rate		0.05 deg/sec

1.4.2.4.2 Power. The total average and peak powers of all the instrumentation are listed in Table 1-6. During the five-day representative experiment all nine sensors are used, and a total of 1.1 MW-min of energy will be required for all of the sensors and the controls. (However, it is unlikely that the radar will be used together with

all of the other sensors because, since the radar is side-looking, its field of view does not superimpose well.) Average energy requirements are:

Sensors: 660 kW-min

Support: 330 kW-min

Data Analysis: 480 kW-min

1.4.2.4.3 Orbit. Observation requirements for the experiment area as a whole are summarized in Table 1-6. The altitude preferred is 185 km (100 n. mi.), but altitudes up to 500 km (270 n. mi.) are acceptable. The actual altitude depends also upon the lifetime desired and the desired interval between repeated overflights. The lowest acceptable inclination for the area is 30 degrees and the preferred maximum is 70 degrees, except for an inventory of ice and snow above the Arctic Circle, where 90 degrees would be necessary.

Some of the geographical mapping done within this experiment area, such as monitoring ice formation and breakup, requires daily to weekly coverage. However, once-a-season coverage generally is adequate for most of the experiment area, including the typical experiment. Mapping of slowly changing forest or urban land use can be done on a yearly schedule.

For all mapping experiments the solar elevation at the target should be 30 degrees or greater. An elevation near 30 degrees can be an advantage for topographical mapping where shadow detail is of value. The cloud cover should not exceed 20%.

1.4.2.5 Potential Role of Man. The general activities of man in setup, operation, and maintenance that are discussed in Section 1.7 apply to this experiment area. The principal skill area required is geographic. A cartographic skill also would be useful for the evaluation of photography, because the ultimate objective of this experimental area is the creation of maps. A photo technician is desirable for the onboard evaluation of photography. During data taking, the crew will decide whether the cloud cover and atmospheric transparency are such that imagery of mapping quality can be obtained. Other duties will consist of servicing the sensors, checking the imagery for quality and coverage, and preparing the data for transport to Earth.

1.4.2.6 Available Background Data. The sources of background data are listed in Section 1.11.

1.4.3 AREA III, AIR AND WATER POLLUTION

1.4.3.1 Objective. The purpose of this experiment area is to detect from space the pollution of air, water, and land resources. The observations will be used to determine the type, source, transport and diffusion mechanisms, and the movement and

ultimate dispersal of pollution over Earth. Sensors, measurement techniques, and computer models will also be developed for operational use.

1.4.3.2 Description. The representative experiment selected for this area is to detect and track the movement of polluted air masses across the United States. Anywhere pollutants are emitted in the air, high concentrations will persist for a considerable length of time. It takes at least days for all the pollution put in by a large city like Los Angeles to be removed. In the meantime the air may reach another large metropolitan area, where an additional dose of pollution is put into it. This behavior is illustrated schematically in Figure 1-8 (from Neiburger, 1969) which shows what the concentration of pollutants might be as the air flows across the United States from Los Angeles to New York.

As the air comes in from the Pacific Ocean, the heavy emissions and poor diffusion over Los Angeles lead to a very high peak in concentration. After the air leaves the Southern California metropolitan area, the improved diffusion and the removal process cause the concentration to fall and by the time it has crossed the desert and Rocky Mountains it has decreased almost to the original background value. The Denver area, the Kansas City area, and St. Louis all cause individual peaks, with the farm areas allowing decreases, but once the air starts crossing the close-together metropolitan areas east of the Mississippi the effects of each area add to the effects of the ones upwind. The highest peak is that at the East Coast.

This experiment will use the air pollution sensors of Table 1-7 to measure the amount of pollutants in the underlying atmosphere across the United States. From these measurements the movement of polluted air masses can be plotted much like meteorologists plot cold or warm air masses for forecasting purposes.

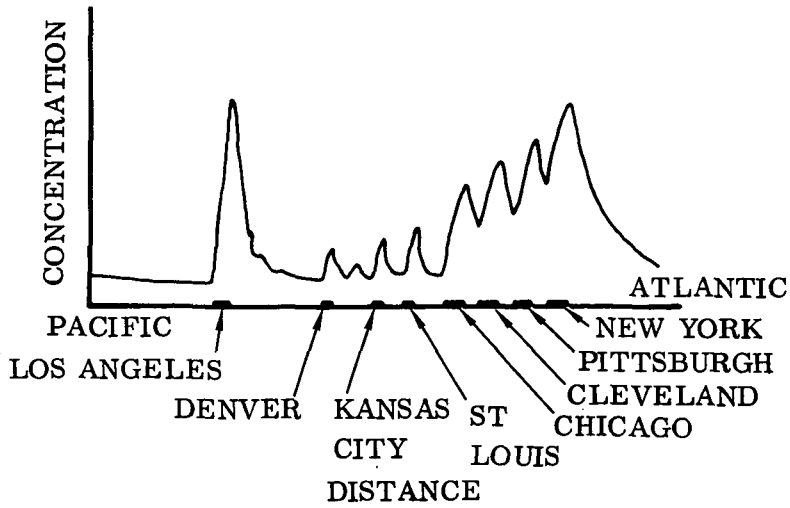


Figure 1-8. Schematic Representation of Pollution Concentration in Air Crossing the United States (Neiburger, 1969)

Table 1-7. Instrumentation and Observation Requirements for Experiment Area III, Air and Water Pollution

Sensor	Weight (kg)	Weight (lb)	Volume (m^3)	Volume (ft^3)	Power Aver(W)	Power Pk(W)
1. Metric Camera	250	550	1.2	42	250	550
2. Multispectral Camera	265	590	.14	5	170	600
3. Television Camera	50	110	.07	2	200	250
4. Multispectral Scanner	135	300	.6	21	190	190
5. Microwave Scanner	100	225	5.6	197	175	175
7. Multispectral Radiometer	18	40	.04	2	20	20
12. Polarimeter	18	40	.06	2	20	45
14. Absorption Spectrometer	14	30	.03	1	15	18
Total	850	1885	7.74	272	1290	2078
16. Telescope and 17. Computer	179	400	.3	12	540	540
18. Data Collection	5	10	.1	1	8	8
20. Controls and Displays	360	800	.7	25	1700	1700
Total	544	1210	1.1	38	1748	1748
22. Maintenance and Repair	258	575	.6	20	50	300
Total	918	2040	1.9	65	1650	1900

Observation Requirements

Season		All
Frequency		Daily and Monthly
Sun Elevation	Pref.	30 degrees
	Accept	30 degrees
Cloud Cover	Pref.	20 percent
	Accept	50 percent
Orbit Altitude	Pref.	185 km (100 n mi)
	Accept	600 km (275 n mi)
Lattitude	Pref.	50 degrees
	Accept	60 degrees
Pointing Attitude Rate		±0.5 degrees 0.05 deg/sec

1.4.3.2 Observation/Measurement Program

1.4.3.2.1 For the experiment area as a whole, most of the observations will be made at the multidisciplinary test sites shown on Figure 1-5. Other sites are:

Water Pollution Sites	Location (latitude, longitude)
Hudson River (industrial pollution)	41°N, 74°W
Gulf Coast (oil spills)	29° to 31°N, 87° to 96°W
Connecticut River estuary (thermal pollution)	41°N, 73°W
West Central Florida (eutrophication of aquatic plants)	27° to 29°N, 81° to 82.5°W
Northern Cook inlet, Alaska (oil spills, tidal flow, and turbulence)	61°N, 162°W

Air Pollution Sites	Location
SO_2 and NO_2 specifically	1. Urban areas, e.g., Chicago, New York, Washington, D.C., Los Angeles. 2. Interurban areas, e.g., Washington-Philadelphia-New York-Boston. 3. Rural areas, e.g., Kansas, Iowa.

The representative experiment for the area will observe these air pollution sites as they are encountered, and also the atmosphere between them.

1.4.3.2.2 Observables. The areal extent and tonal contrast of pollutants in the atmosphere and water will be detected by eye, using the telescope, and recorded by panchromatic and color photography and by a multispectral scanning radiometer. Increased or decreased water temperature caused by thermal or liquid pollution will be detected by the resultant contrast in infrared radiance using infrared and microwave radiometers. An absorption spectrometer will detect gaseous pollutants in the atmosphere by detecting absorption of the reflected sunlight by the gases, and a polarimeter will detect aerosol pollutants by detecting the spectral polarization of the reflected sunlight. Repeated measurements on successive passes over a pollution site will detect the source, movement, and dispersal of the various pollutants.

1.4.3.2.3 Sensors. The total of 8 sensors listed in Table 1-7 will make all of the air and water measurements specified for this experiment area. However, the

representative air-mass-tracking experiment within the area would require only two metric cameras, absorption spectrometer, polarimeter and telescope, since thermal pollution of water is not sought.

Areas of known and suspected fresh and salt water pollution will be photographed with large-field-of-view metric cameras. Panchromatic film will be used in one camera to obtain a high-resolution record, and color film in the other will emphasize the tonal contrasts of visible pollutants. Multispectral cameras with panchromatic film and a green filter will be used for water penetration to identify sedimentation patterns in shallow water. False-color infrared film will enable identification of aquatic plantlife. Infrared film will give high contrast between water and land interfaces.

High-resolution spectroscopy in the near-visual range will enable the detection of pollutants (such as oil slicks) by spectral signature analysis. Thermal infrared imagery from the multispectral scanner will be used to sense thermal pollution and the presence of surface pollutants (by reduction in surface water evaporation rate).

The purpose of the data collection sensor is to gather data from surface-based platforms defining water quality, i.e., saline content, chemical pollution, and radiological pollution.

1.4.3.4 Interface, Support and Performance Requirements

1.4.3.4.1 Data. Data amounts listed below are for the representative air-mass-monitoring experiment. The length was taken as four days, because this is a typical length of time for the rapid movement of an air mass across the United States. On the average, for a 400-km (246 n. mi.) orbit at 55 deg inclination, 7 orbits a day have adequate illumination, but the number of data orbits is limited to 5 by an 8-hour work day, or an average data-taking duration of 60 min/day. If, however, measurements are made only over source areas (an oil spill in the Gulf of Mexico and a seige of smog over New York City are recent examples of this) the duration would be about one-fifth as long.

	Air Pollution Only	All Area III Sensors
Maximum tape-recorded data rate	3800 bit/sec	51.3 Mbs
Total data weight	22 kg (49 lb.)	110 kg (243 lb)
Total data volume	0.09 m^3 (0.65 ft^3)	0.05 m^3 (1.80 ft^3)

Little useful onboard data analysis can be done for the experiment and the photo development facility is not used. Tracking of the polluted air masses will be done by map plotting, much like a weather map, and this is best done on the ground. The

15 minutes of data analysis that is indicated is for analysis of photograph quality to ascertain if the exposure, etc., are correct.

1.4.3.4.2 Power. The total power requirements of the experiment area are summarized in Table 1-7. The average energy requirement for the four-day air-mass-tracking experiment is tabulated below.

Sensors: 310 kW-min

Support: 420 kW-min

Data Analysis: TBD

1.4.3.4.3 Orbit. A ground resolution for water pollution of 100 to 200 feet is required, and this favors an altitude below 400 km. Air pollution research requires a resolution of 4 to 6 km and the altitude can be as great as 560 km (300 n. mi.). If a pollution emergency should arise, a daily repeating orbit, such as 500 km (273 n. mi.) and 55 degrees, is necessary. In practice, it might be more practicable to fly the mission at lower altitudes that cover the Earth in three to six days and to fly the critical areas that arise during the mission by aircraft.

Observations will be made during all seasons on a daily to monthly frequency. Air pollution over source zones requires a daily frequency. Monthly observations will be made during routine patrol for water pollution, while daily observations will be required when a serious pollution event (for example, a large crude-oil spill) occurs. Most sensing techniques require sunlight, so a moderate to high sun elevation is needed. However, thermal pollution sensing might be possible at night, using the LWIR channel of the multispectral scanner to provide an image for orientation purposes.

The surface or troposphere must be observed, so a cloud cover of 20 percent or less is preferred. The location of a pollution event must be fixed within one-third to one mile, except for pollution source research when a fix to a few hundred feet is required.

1.4.3.5 Potential Role of Man. The role of man in setup, operation, and maintenance is discussed in Section 1.7. Special Earth resources skills that are required are meteorological for air pollution, hydrological for water pollution, and oceanographical for ocean pollution. The air and ocean pollution targets are large, and little training of sensors will be required. Fresh-water pollution targets, on the other hand, are much smaller and the research will benefit from target acquisition and tracking with the observation telescope. A major data analysis activity will be selecting spectral bands and monitoring the resulting data for high concentration of pollutants.

1.4.3.6 Available Background Data. The sources of background data are listed in Section 1.11.

1.4.4 AREA IV, RESOURCE RECOGNITION AND IDENTIFICATION

1.4.4.1 Objective. The objective of this experiment area is to gather pictorial, analog, and digital data that will enable hydrologists, agronomists and economists to prepare maps or tables of statistics that locate and identify the soil, plant, tree and, perhaps, animal species in the current and potential agricultural areas of the world. In addition, research and development will be done on collecting data that indicate the moisture content, salt content, organic content, friability, insect population and microorganism content of typical soil classes. These maps and statistics will be compiled by the user, both from historical data from cognizant agencies, such as the Department of Agriculture, and from data supplied by this experiment. Maps and statistics will be created from computerized models that have been developed by the users, supplemented by climatological, meteorological and economic data from other research areas.

An additional objective is to obtain complete photographic coverage of the North and South American continents to be used to construct geological maps for a geologic resource study of the two continents, and to locate new deposits of water, ores, and petroleum. This includes the identification of the type of deposit, estimate of concentration, size and spatial configuration, a geological description of the host formation, and determination of the depth and geographical location of the deposit.

1.4.4.2 Description. The experiments in this area require precise measurements of relatively small areas. Similar experiments done from aircraft have found that sun elevation, season, atmospheric clarity, viewing angle, etc., are all critical. In contrast to the land-use mapping experiments of Area II, the crew must acquire the target and train the sensors upon it for as long as possible. The key sensor is the telescope and a crewman to man it. High spatial and spectral resolution are mandatory. The research will be done almost exclusively with test sites and the duration of data taking will be short.

The representative experiment for this Area is based on the ground tracks over the United States shown in Figure 1-9. Data are taken only when the sun angle exceeds 60 degrees, and this condition is shown by the solid ground-trace lines on the figure. Four orbits have adequate illumination on the first day, but by the fifth day no test sites have adequate illumination. The test sites typically are so small that only 16 minutes of data can be gathered in a single day.

1.4.4.3 Observation/Measurement Program

1.4.4.3.1 Location. Over a dozen different soil types are found in North and Central America and the initial targets will be the multidiscipline and ERTS test

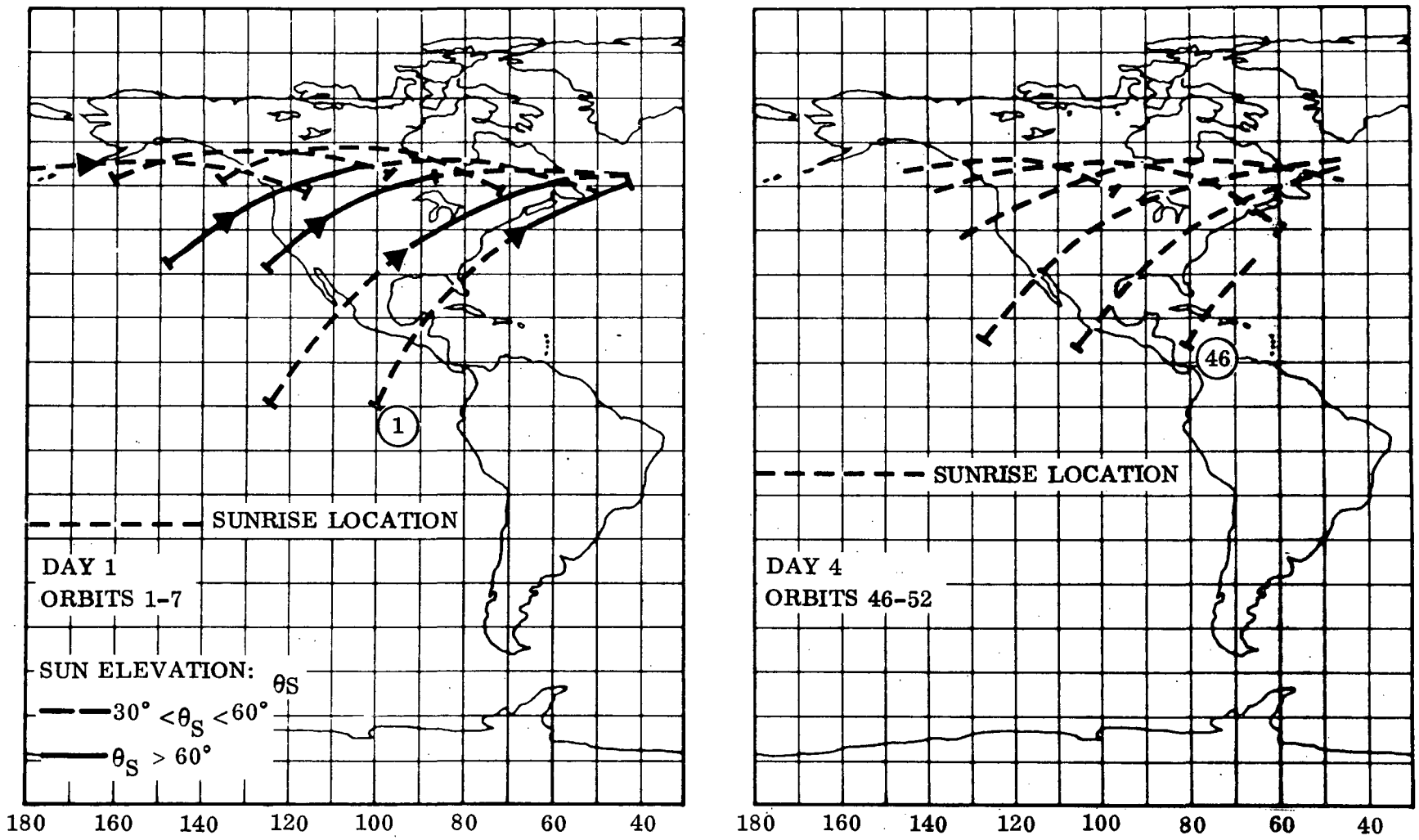


Figure 1-9. Ground Tracks of Representative Experiment for Area IV

sites within these soil and rock zones. Mineral resource test sites will be the existing and potential petroleum provinces and mining districts. A wide range of geology, geography, and topography is represented by targets from the salt dome "islands" of the Mississippi coastal swamps to the permafrost areas of Alaska's north slope and to the mountainous caldera area of Colorado. Weslaco, Texas; Purdue Farms, Indiana; and Davis, California are agricultural test sites.

1.4.4.3.2 Observables. High-resolution photography using panchromatic and false-color film will be used to determine soil, rock and vegetation types, texture, areas of water infiltration, vegetation patterns, standing water, and ground patterns indicative of permafrost. Thermal infrared imagery will be used to obtain temperature patterns of the terrain. Radiometric brightness temperature of the terrain, strongly dependent upon soil moisture content, will be measured with a scanning microwave radiometer. Measurements of true soil moisture and temperature will be obtained by data collection from surface-based sensors for correlation with infrared and microwave measurements.

The variable response of soil bacteria to ultraviolet light may be of significance in oil prospecting. The luminescent qualities of petroleum products are well known and an oil-bearing province well may contrast in the UV with adjacent barren areas. Also, sulfur dioxide, a product of oil seeps, is detectable in the 2850 to 3150 Å region.

Regional fault or major lineament patterns coinciding with metallogenic belts and observed at low sun angles would make favorable targets for finding ore deposits. Likewise, the transverse folds localizing oil, as in the southwestern portion of the San Joaquin Valley, would be desirable to study.

1.4.4.3.3 Sensors. The nine sensors required to do all the agricultural, geological and hydrological resource location and identification experiments of this experiment area are listed in Table 1-8. A large number of sensors are needed because identification of species and resources by remote sensing still is in its infancy and research is needed on the best sensors and spectral bands.

1.4.4.4 Interface, Support and Performance Requirements

1.4.4.4.1 Data. The data amounts listed below are for a representative experiment that lasts for three days over resource identification test sites in the continental United States.

Maximum tape-recorded data rate	50 Mbs
Total data weight	32 kg (70 lb)
Total data volume	0.013 m^3 (0.45 ft^3)

Table 1-8. Instrumentation and Observation Requirements for Experiment Area IV, Resource Recognition

Sensors	Weight (kg)	Weight (lb)	Volume (m^3)	Volume (ft^3)	Power Aver(W)	Power Pk(W)
1. Metric Camera	250	550	1.2	42	500	780
2. Multispectral Camera	265	590	.14	5	170	600
4. Multispectral Scanner	135	300	.6	21	190	190
5. Microwave Scanner	114	255	5.6	197	175	175
6. Microwave Radar	135	300	.12	41	1000	1000
7. Multispectral Radiometer	18	40	.04	2	20	20
10. Multispectral Spectrometer	160	350	.17	6	170	250
12. Polarimeter	18	40	.06	2	20	45
14. Absorption Spectrometer	314	30	.03	1	15	18
Total	1109	2455	7.96	317	2260	3078
16. Telescope and 17. Computer	112	250	.34	8	540	540
18. Data Collection	5	11	.01	1	8	8
20. Controls and Displays	360	800	.7	25	1200	1200
Total	477	1061	1.05	34	1748	1748
21. Data Analysis	608	1335	1.2	40	900	900
22. Maintenance and Repair	258	575	.6	20	50	300
Total	866	1910	1.8	60	950	1200

Observation Requirements

Season		All
Frequency		Weekly
Sun Elevation	Pref.	60 degrees
	Accept	30 degrees
Cloud Cover	Pref.	20 percent
	Accept	50 percent
Orbit Altitude	Pref.	185 km (100 n mi)
	Accept	500 km (275 n mi)
Latitude	Pref.	90 degrees
	Accept	55 degrees
Pointing		+0.5 degrees
Attitude Rate		$\overline{0}$.05 deg/sec

1.4.4.4.2 Power. The power requirements for the Identification Experiment Area are listed in Table 1-8. Energy figures shown below are based on the three-day, (47 minutes of data) representative experiment:

Sensors: 106 kW-min

Support: 82 kW-min

Data Analysis: TBD

1.4.4.4.3 Orbit. The season and frequency of the observation program are summarized in Table 1-8. All seasons are used by one part or the other of the experiment area. In general, weekly observations are required because the identification of resources is based upon the precision measurement of subtle changes. A high sun is preferred for identification experiments because recognition of species and types cannot be done without excellent illumination. For agriculture, measurements should be made close to the time of crop maturity. However, for topographical studies a low (30 degree) sun is preferred, because of the shadow detail it produces. Both east and west illumination is desired, but not essential. There should be a minimum of clouds. Side-looking radar imagery should be obtained from both aspects in mountainous terrain, requiring two separate passes for best results.

A very low 185 km (100 n.mi.) orbit is preferred in order to obtain small ground-resolution-element sizes with current sensors. As sensor resolution improves the orbit altitude could rise. Because geologic research is an important part of this experiment, coverage of the higher latitudes is required.

1.4.4.5 Potential Role of Man. The general role of man in setup, operation and maintenance is discussed in Section 1.7. Special Earth resources skills that will be required are agricultural and geological, since the resources to be located and identified are crop, forests, petroleum, minerals, fresh water, etc. This experimental area is more research oriented than most of the others, and it particularly will require the location and tracking of test sites where known species are located. The principal investigator at the site and the crew will act as a team and direct communication between them is required. Considerable use will be made of the telescope for visual observation and for training the sensors directly on the resource. A large variety of sensors are called out for this area and the crew will experiment with combinations of sensors and spectral bands to obtain the best for the particular resource and the weather condition and illumination existing at the time.

1.4.4.6 Available Background Data. The sources of background data are listed in Section 1.11.

1.4.5 AREA V, NATURAL DISASTER ASSESSMENT

1.4.5.1 Objective. The objective of this experiment is to utilize space observation to provide warning, monitoring and assessment of natural disasters. For example, observations will be made of the extent of rain and snow in the watersheds of flood-prone rivers. Data will be gathered for research in the recognition of the geological precursors of a destructive event, such as an earthquake or volcanic eruption. Research will be done on the feasibility and advantages of using manned satellites for detecting and tracking incipient and active wildfires in forest, range and wild lands. The global distribution of thunderstorm activity also is an objective, because of the close relationship of thunderstorms to severe rain and wind storms (e.g., tornadoes), and to lightning-caused wildfires.

1.4.5.2 Description. Disaster assessment is unique because there are many small areas all over the world where observations will be made, rather than a few large areas. Figure 1-10 shows the worldwide distribution of volcanoes, for example. A single orbit would pass within range of only a few – perhaps three – sites, and the data gathering would last only a few seconds at a time. The largest single disaster-susceptible area is the forest and range lands of western USA shown in Figure 1-11. The widest point is about 1,000 miles or four minutes of orbit, and two, or at the most three, successive orbits would pass over this forest area on a given day. According to the NASA Langley Research Center Study, five to ten orbits per week will

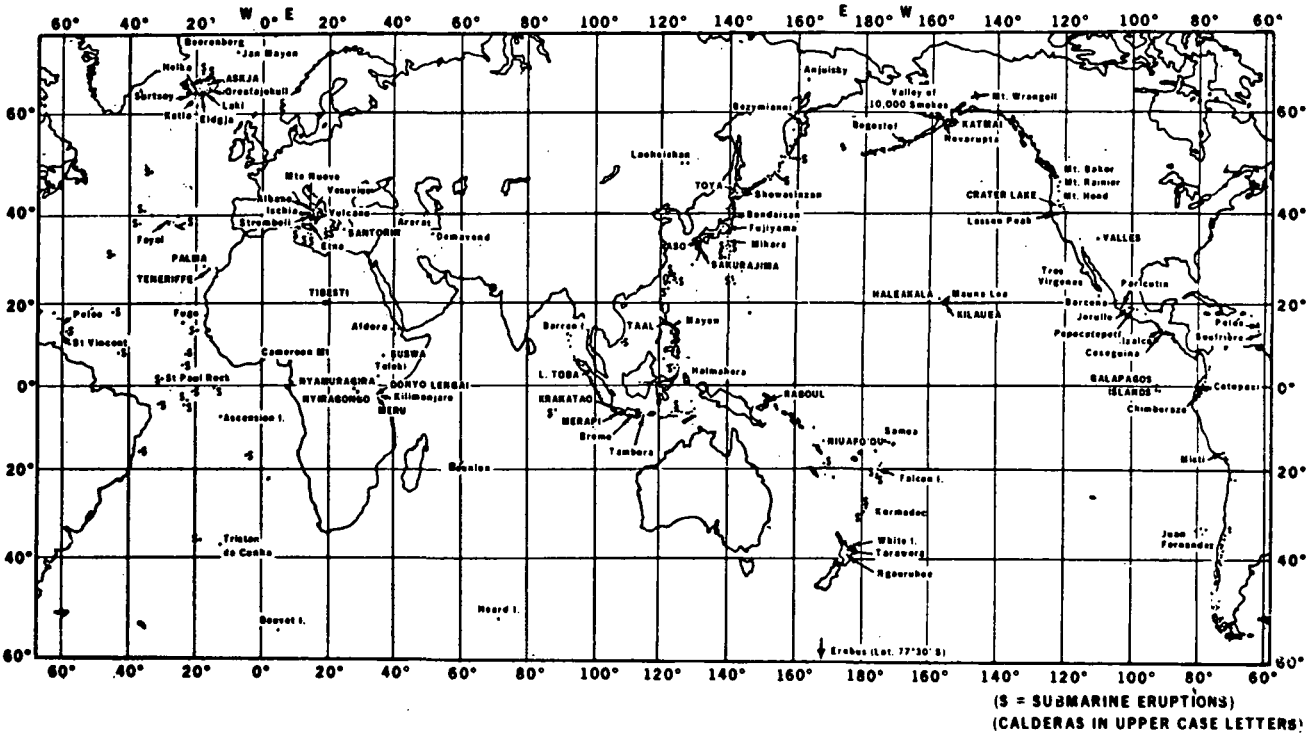


Figure 1-10. Distribution of Some Calderas and Active Volcanoes

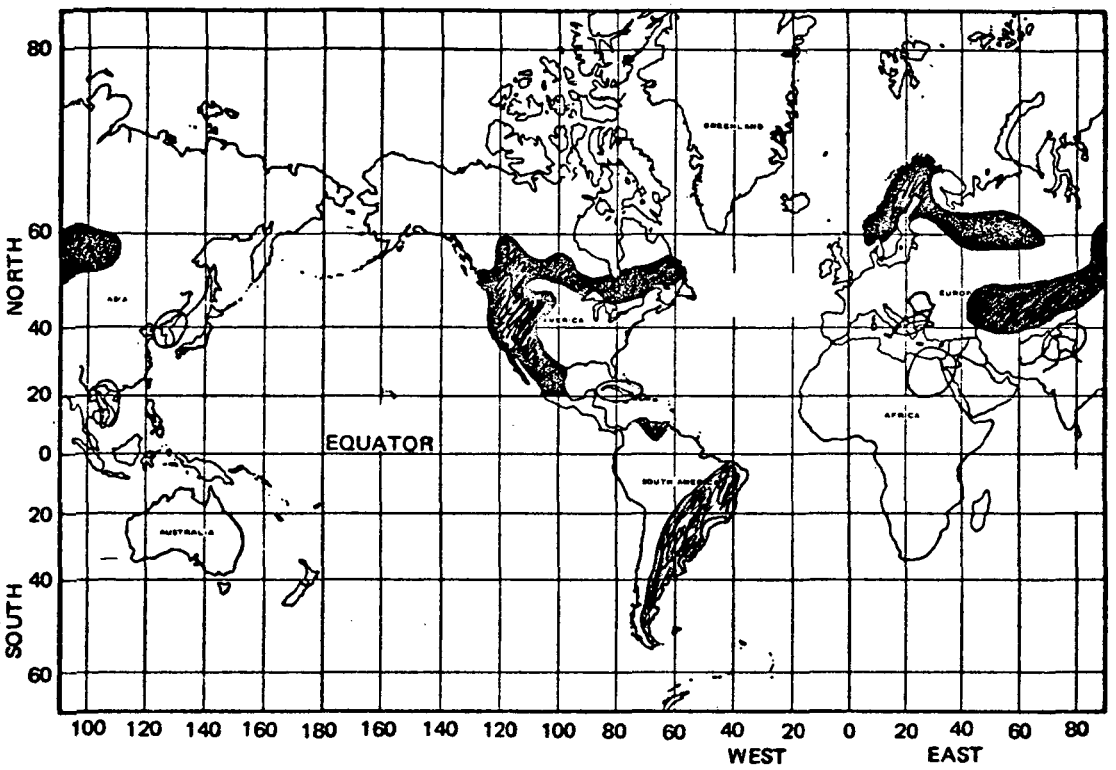


Figure 1-11. Forest and Range Areas Susceptible to Wildfire

collect disaster data. It is deemed logical, then, that a representative experiment duration would be ten orbits per week, of three minutes each. Three minutes represents about 720 miles of ground track. Therefore, data collection is quoted on a basis of 30 minutes of data a week. Since specific target areas are observed, the crew must view the target with the telescope to evaluate the severity of cloud obscuration and, probably, will point the sensors at the target.

1.4.5.3 Observation/Measurement Program

1.4.5.3.1 Location. The flood disaster targets are the major river basins in the Western Hemisphere. Among these are the Mississippi, Ohio, and Arkansas (shown in Figure 1-12), and the McKenzie and Amazon. For geological disasters, target areas are landslide areas near major faults, live volcanoes, and major fracture zones on the sea floor shown in Figure 1-10. Actually, activity will mostly concern targets of opportunity identified by seismic data obtained from surface-based sensing platforms and transmitted to the satellite data collection system. Geology test sites will include the Cascade Mountain volcanoes, Meropi (Indonesia) and Kratatoa (Sumatra).

Forest and range lands that are subject to wildfire are found throughout the world but are concentrated in the parts of the Northern Hemisphere shown in Figure 1-11.

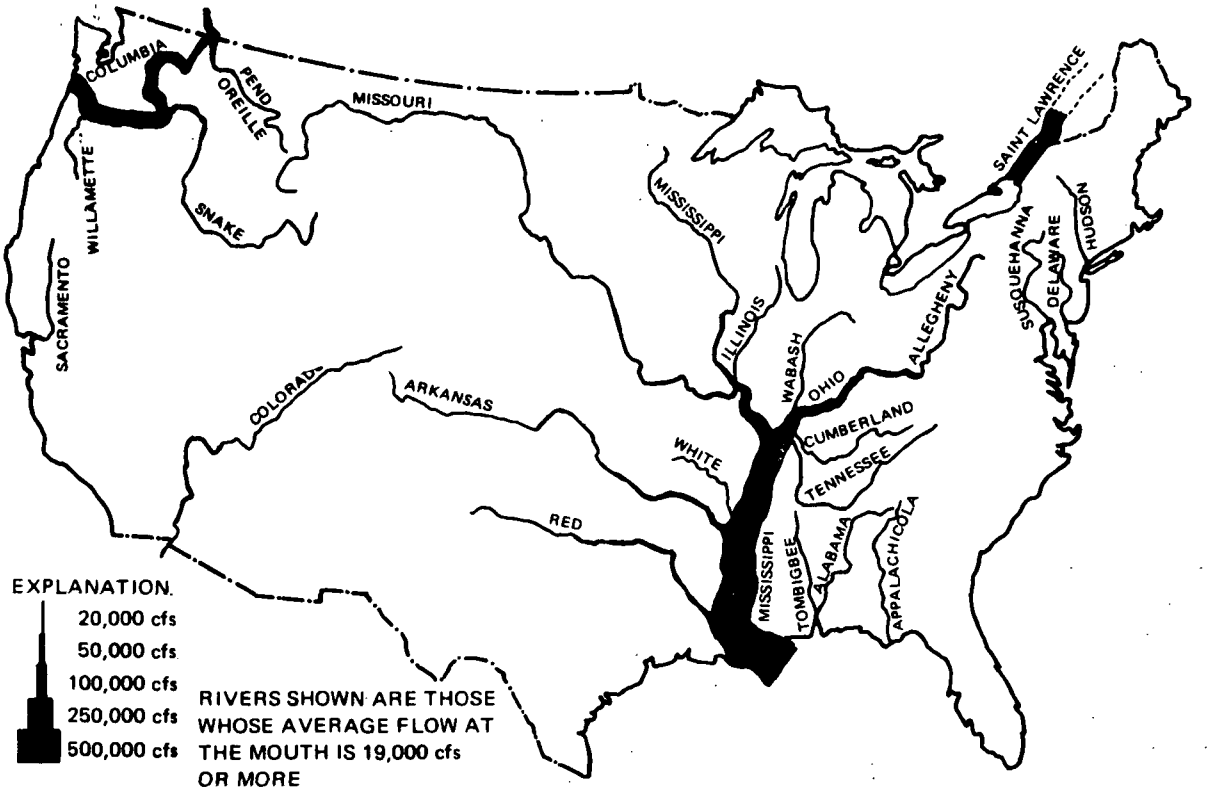


Figure 1-12. Large Rivers in the United States

However, the observations probably should be restricted to North America where they can be coordinated with the current ground and airplane research activities of the U. S. Forest Service.

1.4.5.3.2 Observables. An inventory of snow pack and ice in critical watersheds will be made during overflight with high-resolution cameras, when weather permits. Since most weather-associated disasters occur during bad weather, much of the data probably will have to be taken with microwave sensors.

Earthquake- and volcanic-eruption-prone areas will be surveyed at every opportunity to study the aftereffects of past events and to seek out precursors of future events. Thermal mapping of fractures will be done with both high spatial- and high thermal-resolution sensors. If a disaster occurs, the location should be communicated to the facility immediately, and surveillance of the area for geological changes or thermal activity should take precedence over less timely research. Attempts will be made to locate large storm waves propagated outside the storm center – and perhaps tsunamis – by their solar glitter and radar patterns. When passing over active mining and petroleum areas where subsidence is known or suspected, experiments to measure subsidence with a laser altimeter will be done.

While orbiting over forests or range lands, the scene will be monitored photographically and visually to evaluate the effectiveness of space vs. fire lookout towers for fire detection and their speed in issuance of a fire warning. Onboard photo development will be used here, and the photographs searched for signs of smoke that might escape the narrow field of view of the telescope or the unaided eye.

UHF emissions in the 610 MHz region will be monitored by equipment onboard the spacecraft. During the daytime, cloud scene information (e.g., type, form, distribution and amount) will be included. During the nighttime, visual observations of lightning (e.g., bolts, frequency and length of discharges) will be made.

1.4.5.3.2 Sensors. The sensors used for this experiment are listed in Table 1-9. A single channel of the television camera is used for earthquake, volcano and flood surveillance, and the information can be relayed quickly to the ground for disaster relief purposes. The infrared radiometer is used to detect small or sleeper fires by their thermal radiance. The long wavelength infrared channel of the multispectral scanner also does this, and results of the research may indicate that both are not needed. The microwave scanner and radar will support the infrared scanner during hazy or cloudy weather. An S-band radar imager is specified for structural geology, although an X- or an L-band may prove to be superior. The sferics sensor includes a hand-held viewer fitted with a hydrogen-alpha line (6563Å) filter.

The severity of the attitude requirements depends upon the sensors being used, as shown below. When only film cameras and scanners are used the requirements are least severe. Adding the IR radiometer reduces the latitude in attitude to ±0.5 deg.

	Most Severe Requirement	
	Attitude (deg)	Attitude Rate (deg/sec)
Film cameras and scanners	± 1.0	0.05
IR radiometer	± 0.5	0.05

1.4.5.4 Interface, Support and Performance Requirements

1.4.5.4.1 Data. The data collection media will be film and magnetic tape. Amounts listed below are for a one-week-long experiment with 30 minutes of actual data taking.

Maximum tape-recorded data rate	51.4 Mbs
Total data weight	25 kg (56 lb)
Total data volume	0.010 m^3 (0.363 ft^3)

Table 1-9. Instrumentation and Observation Requirements for Experiment Area V, Natural Disaster Assessment

	Sensors	Weight (kg)	Weight (lb)	Volume (m^3)	Volume (ft^3)	Power Aver(W)	Power Pk(W)
1.	Metric Camera	250	550	1.2	42	500	750
2.	Multispectral Camera	265	590	.14	5	170	600
3.	Television Camera	50	110	.07	2	200	250
4.	Multispectral Scanner	135	300	.6	21	190	190
5.	Microwave Scanner (2)	228	500	11	400	350	350
6.	Microwave Radar	135	300	.12	41	1000	1000
7.	Multispectral Radiometer	18	40	.04	2	20	20
13.	Sferics Detector	10	22	.08	2	6	6
	Total	1191	2412	13.25	516	2436	3196
8.	Data Collection	5	11	.01	1	8	8
16. 17.	Telescope and Computer	179	400			540	540
20.	Controls and Displays	360	800	.7	25	1200	1200
	Total	544	1211	.71	26	1748	1748
21.	Data Analysis	608	1335	1.2	40	900	900
22.	Maintenance and Repair	258	575	.6	20	50	300
	Total	866	1910	2.51	86	2698	2948

Observation Requirements

Season		All
Frequency		Daily and Monthly
Sun Elevation	Pref.	60 degrees
	Accept	0 degree
Cloud Cover	Pref.	20 percent
	Accept	50 percent
Orbit Altitude	Pref.	185 km (100 n mi)
	Accept	500 km (275 n mi)
Latitude (Max)	Pref.	70 degrees
	Accept	40 degrees
Pointing		± 0.1 degrees
Attitude Rate		0.05 deg/sec

1.4.5.4.2 Power. The total of the average and peak powers for all of the sensors required by the experiment area are listed in Table 1-9. Energy figures listed below are for the representative Area V experiment which lasts for ten orbits and collects 30 minutes of data.

Sensors: 67 kW-min

Support Equipment: 52 kW-min

Data Analysis: TBD

1.4.5.4.3 Orbit. Orbit requirements for the Experiment Area are summarized in Table 1-9. The wildfire experiment is done during the local fire season, usually late summer and fall. The flood experiment is done when winter snows are melting in the late winter and spring. Geologic disaster experiments are not season-dependent nor is the sferics experiment, except as it supports the wildfire experiment.

Disaster assessment requires observation every one to three days. When patrolling for a disaster, such as a sudden snow melt causing a flood, a weekly frequency is adequate while a geologic disaster patrol can be done monthly. This experiment is not very sun dependent because parts of it can be done day or night. Photographic portions of the flood and wildfire experiment require a 60-degree solar elevation.

Twenty to thirty percent cloud cover is preferred so large areas can be surveyed pictorially. When observing large, active wild fires the cloud cover could increase to 50 percent. In order to assess the disaster the targets must be located to within one-half mile. Spatial resolution requirements are severe and favor as low an orbit altitude as practicable. An altitude of 185 km (100 n.mi.) or less is preferred. Another factor is the interval between over-orbits. Disaster assessment requires a one- to three-day repeat interval and forecasting requires a frequency of one week to one month.

1.4.5.5 Potential Role of Man. The role of man in setup, operation and maintenance is discussed in general in Section 1.7. Disaster warning will be provided by monitoring disaster-prone areas. Detection of incipient disasters probably will be done by an automatic alarm on the sensors (a hot-spot alarm, for example) or by study of the data by ground-based scientists. An exception will be scanning photographs of forest and range areas for smoke from wild fires. This can, and should be, done aboard the facility, because time is of the essence. However, once a disaster is imminent, such as the sudden melting of a snow-pack, or a disaster has occurred, such as a flood, the crew will become directly involved in training the sensors on the disaster area, in direct visual examination of the scene with the telescope, and in giving verbal description directly to the ground. Special skills required are meteorological, for tornadoes and hurricanes; geological, for eruptions and earthquakes; hydrological, for floods; and agricultural, for wildfires.

1.4.5.6 Available Background Data. Sources of background data are listed in Section 1.11.

1.4.6 AREA VI, OCEAN RESOURCES

1.4.6.1 Objectives. The objective of this experiment is to do research in locating and measuring ocean currents, both wind-driven and geostrophic, upwelling and sea surface roughness associated with wind stress. Results will be applied to fisheries, ship routing, and long-range weather forecasting.

1.4.6.2 Description. Observations of ocean temperature, color, and roughness will be made from space. Orbits that pass over the proper portions of the ocean will be selected beforehand and the crew will activate the sensors at the correct time. Particular care will be necessary to coordinate the space data with data taken from ships and aircraft in the same area. Relatively few sensors are used and these tend to be radiometers to detect temperature or color differences.

Ocean resource areas are very large and oceanographic experiments tend to be of long duration. The representative experiment for this Area is of this type. An orbit was selected that follows the Japanese current along the east coast of Asia and into the Gulf of Alaska. Research will be done on current tracing and upwelling detection, using primarily thermal and color sensing. A total of 60 minutes of data taking is possible each day and the model experiment is assumed to last for seven days.

1.4.6.3 Observation/Measurement Program. Observations will be made over the world's oceans and seas, but will tend to concentrate in traveled areas where commercial ships, weather ships, buoys and airplane data are also available. Argus Island at 32.3°N, 64.7°W is a typical island truth site. Fisheries research will be done in the known fishing areas, such as the Gulf of Alaska, West Coast of Peru, and Newfoundland Grand Banks. Ocean Resources experiments could be done in conjunction with the Meteorology and Atmospheric Sciences Experiments when the ocean areas of interest to the oceanographers and the meteorologists coincide.

1.4.6.3.1 Observables. Currents and associated upwelling result from wind drag, water density differences, tides, and internal waves and can be detected by temperature differences and color. It is generally assumed that the large-scale quasi-permanent currents are associated with differences in sea surface height relative to the geopotential surface. It is actually the slope of the sea surface that is the pertinent parameter and perhaps this elevation change can be measured. Once these currents are known, transports of mass and heat can be estimated. In addition, the current structure beneath the surface can be estimated if the density field is known, and the density field can be determined if temperature and salinity data are available from hydrographic soundings made from the surface.

Sea surface roughness and the resulting swell are determined mainly by the wind stress on the sea surface and can be estimated from its radar backscatter characteristics. The theory relating the wind distribution to the roughness is quite well developed but further development and use is limited by the lack of observations. Sea surface roughness is one of the parameters associated with surface heat loss and gain that determines the mixed layer depth. These parameters also work together to form turbulence.

1.4.6.3.2 Sensors. The five sensors listed in Table 1-10 will be used for various parts of this experiment. Only the long wavelength infrared channel of the multispectral scanner is required for surface temperature contours. Two microwave scanners are listed, because it appears that surface roughness determination will require two separate frequencies and polarizations. The scatterometer is a combination of a microwave radiometer, a scatterometer, and a radar altimeter between 13.4 and 14.2 GHz and operates at linear and cross polarizations (not simultaneously).

1.4.6.4 Interface, Support and Performance Requirements

1.4.6.4.1 Data. Photographs of large areas of the oceans will be needed for research in winds and surface roughness by sun glitter and cloud patterns. Otherwise, all data will be recorded on magnetic tape and computers will be used to develop maps and statistics of ocean temperature, current location, surface roughness, and the like. The multispectral television data on ocean color will be processed into pictures of the ocean surface in very narrow bands for research in the spectral signatures of phytoplankton, zooplankton and other nutrients.

The representative experiment for the experiment area is a survey of the Japanese current from near the equator into the Gulf of Alaska. A roughness, current, and fisheries experiment could be performed during a portion of four orbits that pass over the western Pacific Ocean and into the Gulf of Alaska. The length of the data-taking period could be about 15 minutes on each of the four orbits. These four orbits, plus the experiment setup and termination time, would take up one eight-hour day. If the experiment is run for seven days the data amounts will be:

Maximum tape-recorded data rate	51.3 Mbs
Total data weight	165 kg (367 lb)
Total data volume	0.08 m^3 (2.68 ft^3)

1.4.6.4.2 Power. The total power requirement of each of the sensors for the Experiment Area is listed in Table 1-10. Since the oceanographic signatures are not, in general, observable by conventional photography, the photo development support facility is not included. The average energy tabulated below is for the seven-day representative experiment that has a duration of 420 minutes.

Table 1-10. Instrumentation and Observations Requirements for Experiment Area VI, Ocean Resources

Sensors	Weight (kg)	Weight (lb)	Volume (m^3)	Volume (ft^3)	Power Aver(W)	Power Pk(W)
1. Metric Camera	250	550	1.2	42	500	780
3. Multispectral Television Camera	50	110	.07	2	200	250
4. Multispectral Scanner	135	300	.6	21	300	190
5. Microwave Scanner (2)	228	500	11.	400	350	350
9. Scatterometer	74	163	.3	11	153	300
Total	737	1623	13.17	476	1393	1870
18. Data Collection	5	11	.01	1	8	8
20. Controls and Displays	360	800	.7	25	1200	1200
Total	365	811	.71	26	1208	1208
21. Data Analysis (Electronic)	300	665	.6	20	400	400
22. Maintenance and Repair	258	575	.6	20	50	300
Total	558	1240	1.2	40	450	700

Observation Requirements

Season		All
Frequency		Daily
Sun Elevation	Pref.	60 degrees
	Accept	30 degrees
Cloud Cover	Pref.	20 percent
	Accept	50 percent
Orbit Altitude	Pref.	185km (100 n mi)
	Accept	460km (250 n mi)
Latitude	Pref.	90 degrees
	Accept	50 degrees
Pointing		+0.5 degrees
Attitude Rate		0.05 deg/sec

Sensors: 590 kW-min

Support: 510 kW-min

Data Analysis: TBD

1.4.6.4.3 Orbit. This experiment will be performed in all seasons, with observations made daily. Radiometric measurements of roughness and temperature can be made day or night. Photographic observations of solar glitter and of sea surface color require a solar angle greater than 30 degrees, and the determination of the best angle is actually part of the experiment. Cloud-cover photography prefers a

60-degree solar elevation and some degree of shadowing. A cloud cover of 20 percent or less is preferred, although up to 50 percent may be acceptable for the visible and infrared measurements.

The orbit altitude should be low enough that the surface-resolution-element size with available sensors is no larger than 90 meters (300 ft) and the area covered is 90 × 90 km (50 × 50 n.mi.). The NASA Langley Research Center study specifies that the altitude be less than 370 km (200 n.mi.). The orbit inclination must be 50 degrees or greater.

1.4.6.5 Potential Role of Man. All of the general activities discussed in Section 1.7 are applicable here. Duties are largely routine maintenance of the sensors, turning them on and off at the proper time as directed from the ground or by an onboard computer. The signatures in general are not amenable to direct visual observation – except cloud cover – and very rapid processing is not vital; therefore, the role of man will be evaluation of the collected data for electronic quality and experimental usefulness. The special skill required is oceanographic, although a meteorological skill also would be valuable, because oceanography and meteorology are intimately related disciplines.

1.4.6.6 Available Background Data. The sources of background data are listed in Section 1.11.

1.4.7 AREA VII, SPECIAL RESEARCH

1.4.7.1 Objective. The Special Research experiment category includes all observations and measurements that are too developmental in nature or too restricted in application to be ready yet for a specific experiment area. An example is a laser used as a line scanner. This category also includes research in onboard data analysis, interpretation, and experiment planning. An example here is the precision development of 130 mm (5 in) or 240 mm (9.5 in) metric camera film and the photoanalysis of the resulting negatives.

1.4.7.2 Description. These experiments cannot be described here because they have not yet been conceived in detail. However, some typical proposals are:

a. Laser line scanner

b. Direct transmission of high resolution television imagery

c. Processing of large size panchromatic film

d. Processing of color film

e. Precision analysis of metric camera photos

f. Concurrent experiments using ground, airplane, sounding rocket and meteorological satellite-mounted sensors

1.4.7.3 Observation/Measurement Program. The targets will be highly instrumented test sites or special resource areas selected particularly for the research. The data analysis parts of the experiment will require direct communication with a counterpart scientist at a ground-based data analysis center.

The sensors or the measurement techniques will tend to be research and development in nature. Several of them are listed below from Table 1-2, Items 12 through 15. These sensors, typically, are unique to certain experiment areas, but their development has not progressed to the point that they are operational for space.

12 Polarimeter

13 Sferics Detector

14 Absorption Spectrometer

15 Optical Radar

Panoramic Camera

Photo Processor – 240 mm film

Photo Processor – color film

A space-qualified 11 cm (4.5 in) return-beam vidicon camera is cited as a supporting technology development (STD) item in the Langley Research Center study. It has a ground-resolution-element size capability of about one-tenth the size of the current television camera. Ultimately, multispectral television cameras should replace the film framing cameras.

A high-resolution multispectral scanner also is cited as an STD item by NASA/Langley. A ground resolution of 100 feet and temperature resolution of 0.2°K are sought. The unique feature is the use of high-density linear arrays of detectors, each consisting of several thousand individual elements.

The optical radar is often called a laser line-scanner, and is used to produce images of the terrain in visible and infrared wavelengths. The research also would include the laser as a profiler for precision height measurement.

There still is uncertainty about the best radar frequency and type. The research will include a tradeoff analysis of L-band, with its penetration capabilities, and X-band, with its resolution capabilities. Whether or not fully focused synthetic-aperture radar truly is superior to unfocused or to real-aperture radar also will be evaluated.

Ideally, all sensors should be pointed directly at the resource area. This might be accomplished by slaving all sensors to the observation telescope. The telescope itself could be trained by a crew member or by a computer that has been programmed by the crew. A major problem here is mounting the large cameras and antennas in such a way that they can be trained.

It has been contended that the panoramic camera is superior to the photogrammetric camera for observing resources from space. This contention could be evaluated as a special research item.

Development of a facility for onboard processing and electronic readout of metric and multispectral camera film is a supporting technology development item in the Langley study. This should be expanded to the onboard photo analysis of the processed negatives, including black and white, false-color, and broad-band color.

1.4.7.4 Interface, Support and Performance Requirements. No attempt has been made to specify the interface requirements, because these experiments and their associated hardware are not yet well enough defined. The specifications listed in Table 1-2 can be used as a preliminary estimate for these developmental sensors.

1.4.7.5 Potential Role of Man. These experiments require that a skilled researcher be present aboard the facility to personally direct the activity. Sensors will be operated under his direct control; he will select targets, and he will do much analysis of the results and planning of the next data run. It is anticipated that a special group of experimenters will be trained to perform each item of special research, and that they will be brought up to the space platform with the equipment.

1.4.7.6 Available Background Data. Sources of background data are listed in Section 1.11.

1.5 INTERFACE, SUPPORT AND PERFORMANCE REQUIREMENTS

1.5.1 SUMMARY OF GROWTH REQUIREMENTS. Anticipated requirements of the facility, as they affect interface and support from a module, Shuttle, or Space Station are summarized in Table 1-11. These summary data represent, in the best judgment of NASA scientists, the overall facility and experimental requirements to accomplish a realistic experimental program. Rationale for selection of the summary parameters is, in some instances, arbitrary but has as a basis the total NASA experience and knowledge of prior flight and experiment definition and integration programs.

The weight, volume, power and data rate listed have been increased by ten percent over those shown in Table 1-2 to allow for anticipated future growth. Support consists of Support Specification Items 16 through 22 from Table 1-2. The 368 kg (820 lb) of logistics consists of repair parts and replacement sensors, and the consumables consist of magnetic tape, film and cryogenics. The power figure is the average required by Experiment Area II, World Land Use Mapping, which is the largest power consumer. It is assumed that the sensors and support equipments are put on standby and the Data Analysis and Maintenance and Repair units are activated during data analysis.

Table 1-11. Interface and Support Requirements Summary

	SENSORS	SUPPORT
Weight	1840 kg (4070 lb)	1650 kg (3650 lb)
Volume	22 cu. m (790 cu. ft.)	4 cu. m (140 cu. ft.)
Power (Avg. Ext. Area II)	Data Taking Mode - 4.5 kw Data Analysis Mode - 1.6 kw	
Crew Skills	Meteorology, Oceanography, Geology Geography, Cartography, Agronomy, Hydrology	
Maximum Tape-Recorded Data Rate	51 M Bits/Sec.	
Logistics Up (30-Day Avg.)	368 kg (820 lb.)	Consumables 197 kg (437 lb)
Logistics Down (30-Day Avg.)	368 kg (820 lb.)	Consumables 197 kg (437 lb)
Pointing - Accuracy	$\pm$8 mr ($\pm$0.5°)	
Stability	$\pm$0.8 mr/sec. ($\pm$0.05°/sec.)	
Orbit - Altitude	185 km(100 n.mi.), desirable	
Inclination	1.57r (90°), desirable; 50° acceptable	
Unique Environmental Requirements: Minimum contamination; protection of film from radiation, temperatures		
Support Items: Observation telescope, controls & displays, data analysis, maintenance & repair, etc.		

If the sensors are turned off, as would be done after the last data run, the average power drawn would be reduced to 950 watts for the Data Analysis and Maintenance and Repair units alone.

1.5.2 RANGE OF REQUIREMENTS. The range of requirements is given in Table 1-12. The minimum value and the maximum value of several system design parameters are tabulated. The first seven requirements apply to the experiment areas generally, while the last five depend upon the representative experiments that are being performed within the experiment areas. The duration of the experiment is the design driver for the last five parameters.

Table 1-12. Range of Requirements

	Minimum Requirement	Maximum Requirement
FOR EXPERIMENT AREAS		
No. of Sensors	5	9
No. Sensor Support Equipments	2	3
Equipment Weight (kg)	1402	3145
(lb)	3099	6744
Equipment Volume (m^3)	10.7	21.3
(ft^3)	375	744
*Average Power (watt)	2601	4135
Orbit Altitude (km)	185	TBD
(n.mi.)	100	TBD
Orbit Inclination (rad)	0.87	1.57
(deg)	50	90
FOR REPRESENTATIVE EXPERIMENTS		
Experiment Duration (min)	30	420
Digital Data (bits/sec)	3800	51.4M
Tape & Film Weight (kg)	23	179
(lb)	51	398
Tape & Film Volume (m^3)	0.013	0.068
(ft^3)	0.44	2.42
Average Energy (kW-min)	120	1135
*Sensors and sensor support equipments (No. 16-20) only		

The least number of sensors required by any of the seven Experiment Areas is five for Area VI; the maximum number is nine for Areas I, II, IV and V. Area II requires the maximum average power. The air-mass-tracking experiment of Area III has the lowest data rate, since neither the Multispectral Scanner nor Television Camera are used. The minimum tape and film weights, however, are for the typical experiment in Area I, because the radar imager is not used.

1.5.3 DATA. The maximum data rate is set by the Multispectral Scanner whose 50 Mbs data rate is very much greater than any other sensor whose output is tape recorded. The Radar Image rate is 150 Mbs, but this is recorded on film and returned to the surface in this form. If the Multispectral Scanner also were recorded on film, the maximum data rate for the representative experiments would drop to 1.4 Mbs (Area V), and the design driver would be the Multispectral Television Camera.

The principal contributor to tape and film weight are the Multispectral Scanner and the Radar Imager. The weight and volume figures listed on Table 1-12 assume a magnetic-tape packing density of 10^6 bits/inch, and a 70-mm film packing density of 15.5 kilobits/mm^2. Advanced recording techniques will be required to record at these packing densities.

The minimum data rate is set by the air mass experiment in the Air and Water Pollution Area. This experiment utilizes only the Metric Camera, Absorption Spectrometer, and Polarimeter that do not produce large quantities of digital data.

1.5.4 POWER. Experiments in Areas II, World Land Use Mapping, and IV, Resource Recognition, are the power subsystem design drivers. They utilize nine sensors, one of which is the 1000-watt radar imager. Oceanographic experiments in Area VI should consume the least power, because only five sensors are required and no radar.

The design driver for the energy collection (e.g., solar panels) or storage subsystem (e.g., batteries) is Area II, Land Use. This is due to the relatively high power requirements of the 9 sensors and the 275-minute duration of data-taking for the representative experiment in this Area. The energy requirement of Area V is among the lowest because, although the power requirements are high, the typical data-taking duration is only 30 minutes.

The duration of a representative experiment within each Experiment Area is tabulated in Table 1-5. The duration of data-taking for disaster-type experiments is expected to be the least, because the disaster-prone areas are small in size and only about four minutes a day is required to observe them. Oceanographic experiments typically can have the longest durations, since the area of relatively homogeneous ocean is far larger than the area of any homogeneous land resource area.

Figure 1-13 is representative of the detailed power duty cycle of the sensors of a facility experiment. It covers through the second data run of an experiment in Area

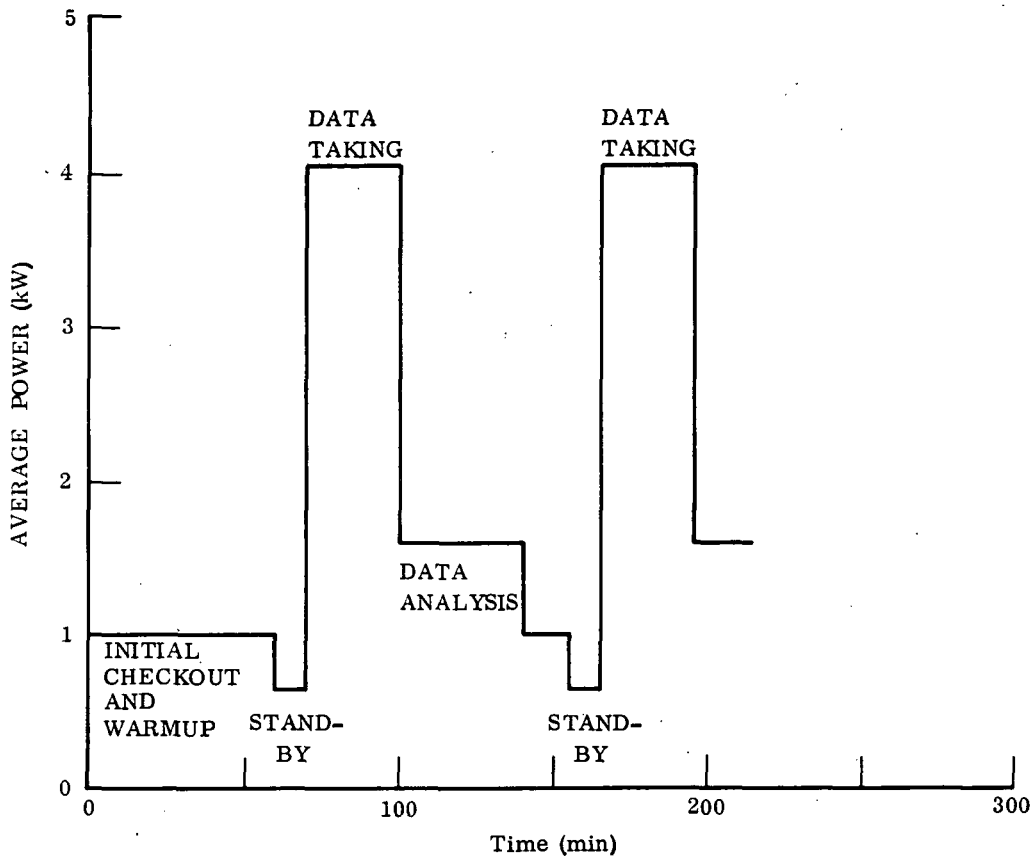


Figure 1-13. Power Profile for Typical Land Use Experiment

II, Land Use Mapping. Prior to the data run about 60 minutes are required to warm up and check out the instrumentation. On subsequent passes only 15 minutes are assigned to warmup and checkout. Checkout should be scheduled so a 10-minute standby period is available in which to get set to take data. The typical duration of an individual data-taking run for Area II is 30 minutes, and this is followed by a 40-minute period of data analysis. The power consumption of 1.6 watts assumes the sensors are put on standby. Prior to the next data run, there is a briefer warmup and checkout period and another 10-minute standby period.

1.5.5 POINTING. The principal requirement imposed on the carrier vehicle is that the sensor platform must be pointed down toward the nadir. Exact pointing and attitude rate requirements for each sensor are given in matrix format in Table 1-2. The most severe requirement for sensor pointing is ±8 mrad (±0.5 deg), and for attitude rate it is the 0.175 mrad (0.01 deg)/sec of the aeronomy spectrometer; although a more common requirement is 0.8 mrad (0.05 deg)/sec. The duration of the attitude hold is the duration per pass in the Experiment Time Limits column of Table 1-5.

1.5.6 ORBIT ALTITUDE. Some of the experiments require ground resolutions of 30 meters (100 ft) or less, and current or developmental sensors cannot achieve this resolution unless the orbit altitude is low. An altitude of 185 km (100 n.mi.) probably

is the lowest practicable altitude, but the maximum cannot yet be determined. As sensor resolution is improved, the maximum altitude will increase.

1.5.7 ENVIRONMENT. The environmental requirements internal and external to the facility are summarized in Table 1-13. The module cleanliness class should be 100,000. Dissipation by the sensors and associated instrumentation can cause problems unless an adequate heat transfer subsystem capable of removing between 2.0 and 3.0 kW of dissipated power is available. Developing reliable quantitative data on the acceptable radiation environment for photographic film is difficult, but the range of tolerance levels for film is generally assumed to bracket the maximum acceptable tolerance levels for man.

1.5.8 CONSUMABLES. The long wavelength infrared detectors must be cooled with liquid or solid cryogen. Nitrogen and argon have been suggested, and in either case about 100 mW of power from each detector must be absorbed by the cryogen. An evaporative refrigerator with resupply of liquid nitrogen at intervals from the surface probably is more readily available, at least in the early years, than a recycle type. The weight of liquid nitrogen that will be consumed during the data-taking portion of each experiment area is also tabulated in Table 1-2. The listed amount assumes 0.32 grams/min (7×10^{-4} lb/min) of nitrogen each will be required for the multispectral radiometer and scanner when they are used. The weight listed might be increased by a factor of two or three to account for the chilldown of the sensor.

1.6 POTENTIAL MODE OF OPERATION

Three types of operation have been considered: Shuttle-Sortie, Space Station integral, and Experiment Module. With the Shuttle-Sortie mode the experiment equipment is carried into orbit as payload by a Shuttle, is operated for up to 30 days by a small crew, and then returned to the surface with the Shuttle. The Space Station integral mode implies that the Earth Observations Facility is integral with a Space Station that can supply a sizable operating crew, power, data management, etc. The Experiment Module mode is similar to the Space Station except that the facility is contained within a module that is launched separately and permanently docked to a Space Station. Compatibility with these types of operation is indicated in the following table.

Type of Operation	Compatibility	Comments
Shuttle-Sortie	Partial	Data Analysis and Maintenance sub-facilities cannot be accommodated with current Shuttle payload capability.
Space Station Integral	Complete	Special provision for nadir pointing required.
Experiment Module	Nearly Complete	Complete modularized facility too large for Shuttle payload.

Table 1-13. Environment Summary

Operational Phase / Environment	Prelaunch	Launch and Ascent	Orbital Coast	Orbital Operation
Film Storage				
Temperature (^{o}K) (^{o}F)	280 to 295^{o}K	280 to 305 ^{o}K	280 to 295 ^{o}K	280 to 295 ^{o}K
Humidity (% RH)	0 to 55	0 to 95	0 to	30 to 55
Facility Interior				
Acceleration (g)	$\pm$2 Flight Axis $\pm$0.5 Lateral Axis	6.0 Flight Axis 4.0 Lateral Axis	$\pm$1 Flight Axis $\pm$1 Lateral Axis	N/A N/A
Vibration	MIL-STD-810B Method 514 Proced. X, Part 3	TBS	20-80 Hz at +3 dB/ octave 80-2000 Hz at 0.006 g^2/Hz	N/A
Shock	MIL-STD-810B, Method 516 Proced. 1-20 G Basic Design Proced. 11-Transit Drop Proced. V-Bench Handling	N/A	730 Peak Response	N/A
Acoustic Noise	N/A	138.1 dB	N/A	N/A
Radiation (rad/day)	N/A	N/A	0.9	0.9
External				
EMI	Note 1	Note 1	Note 1	Note 1
Light	Note 2	Note 2	Note 3	Note 4
Contaminants	Notes 5,6,7,8,9	N/A	N/A	Overboard Dump Material

Notes:

1. MIL-E-6051C.
2. MIL-STD-810, Method 505
3. 1.37 x 10^5 Lux, 2,000 A to 30,000 A.
4. 250 Lux, 3,500 A to 7,500 A (sunlight through vehicle windows or on uncovered optical collectors)
5. MSFC-Spec-164, MSFC-Proc-151, MSFC-Proc-166C, MSFC-STD-246A, and MSFC-STD-343A.
6. Fungus - MIL-STD-810, Method 508.
7. Sand and Dust - MIL-STD-810, Method 510
8. Salt Fog - 5% Solution for 50 hr, MIL-STD-810, Method 509
9. Rain - 4 $\pm$ in./hr, MIL-STD-810, Method 506.

The accomplishment of the FPE objectives was considered for three specific modes: a) on-orbit stay-time limited to 30 days as with a Space Shuttle, b) extended on-orbit stay-time revisited periodically by a Shuttle, and c) extended on-orbit stay time for a Space Station. The conclusions are summarized below.

Earth Observations Facility Experiment Areas		Accomplishment of Objectives Mode A	Mode B	Mode C
I	Meteorology & Atmosphere	Yes	Yes	Yes
II	Land Use Mapping	Uncertain	Yes	Yes
III	Pollution	Yes	Yes	Yes
IV	Resource Recognition	Uncertain	Yes	Yes
V	Disaster Assessment	Yes	Yes	Uncertain
VI	Ocean Resources	Yes	Yes	Yes
VII	Special Research	TBD	Yes	Yes

Accomplishing the Land Use Mapping and Resource Recognition objectives with Mode A is uncertain because the identification of some kinds of land use or of resource species may require a longer term of observation than 30 days. However, if a series of Shuttles can be used to extend the observations for a complete 90 day season, the evaluation changes to yes.

Mode C is rated uncertain for Area V because the orbit is fixed. A disaster might occur off the ground track where the Space Station will not overfly soon enough for useful observation.

1.7 ROLE OF MAN

1.7.1 ADVANTAGES OF MAN. An advantage of having man aboard the facility is his remarkable talents for mentally processing large amounts of data by rejecting irrelevant information and concentrating on the particular signatures that he is seeking. He has a comprehensive ability to recognize important features and to do onboard data correlation and signature recognition. Once a particular type of target is selected, he quickly can make decisions on the specific measurements that should be made and on the relative importance of the results. The descriptive material that man provides verbally can convert qualitative observations into valuable quantitative data by relating them to the overall framework of the investigation. Another advantage of the presence of man is that he can monitor the field of view of the sensors, evaluate the illumination on the surface, judge contrast, and select the best measurement technique for the particular problem. In some cases, an early oblique view might be of much greater immediate value than a later orthographic view.

The ability to select and operate the right instruments at the right time to solve a particular problem might be one of the greatest advantages of having man present in the facility. Decisions could be based on observations made by looking ahead of the spacecraft, on observations made on previous orbits, or on information transmitted from the ground to space.

Another advantage is the use of the Observation Telescope. The telescope is a high-resolution optical sensor, and high-resolution imagery is a requirement of almost all Earth resource scientists. None of them require complete coverage of vast areas, but all require some high-resolution sampling. The astronaut can point certain sensors precisely by sighting through the telescope and be assured that the feature is located in the center of the field of view of the sensor. The telescope is a sensor which need not make a record – the astronaut can evaluate the scene and in many cases determine whether an anomaly is present and whether the circumstances justify additional observation. In any case, the astronaut can apply scientific judgment to both periods of planned sensor operation and targets of opportunity.

The crew will do sensor modification, calibration, and maintenance. An example is a multispectral scanner used as a test bed for various filter-detector combinations. The ability to change these components frequently and rapidly could be advantageous to research in remote recognition of resources. Man can be trained for visual observation and inspection, especially when observations of the specific environmental factors affecting the interpretation of the sensor data would be valuable. An example here might be a knowledge of the degree to which clouds, haze, atmospheric contaminants, etc., would affect the quality of photographic, IR, and microwave measurements. Man will be an advantage for those experiments that require visual target acquisition and accurate pointing, e.g., high-resolution imagery of a disaster area (fire, tornado, earthquakes, floods, etc.) to determine the amount of damage done.

1.7.2 TASKS. The tasks which the crew members will perform on facility equipment, including sensors, data processing and support, are:

a. Initial installation and checkout, including calibration and alignment.

b. Operate sensors and observe performance.

c. Quick-look data evaluation.

d. Shutdown and storage.

e. Data evaluation, discrimination, and transmittal.

f. Maintenance, repair, and replacement.

g. Consultation with researcher on the ground.

h. Mission planning.

A typical duration of each task is given in Table 1-14 and the task itself is described in the balance of this section. For some Experimental Areas, up to three scientific skills are desired, and these are designated simply as numbers I, II, and III. Typical tasks are listed for each crew member.

1.7.2.1 Initial Installation and Checkout. The crew must unpackage the instruments and obtain baseline characteristics of each sensor. The system will be activated and prepared for operation. Instrument checkout will require the crew to activate the cryogenic systems, load film, calibrate, align, and ensure the instruments are prepared for data-taking operations.

1.7.2.2 Operate. During the experiment operation the crewman must acquire the target, evaluate the "seeing" conditions, activate the sensors, perhaps track the target, and monitor the electronic quality of the sensor output.

1.7.2.3 Quick-Look Data Evaluation. The data, both film and electronic, will be evaluated on a quick-look basis between data runs, to check quality and proper sensor operation.

1.7.2.4 Shutdown. After the experiment is over, the sensors will be shut down until the next Earth resources experiment. The film will be removed, cryogenics turned off, lens covers installed, etc. Between the individual data-taking passes, the sensors may be either put on standby or shut down, depending on the circumstances.

1.7.2.5 Evaluate Data. The evaluation, typically, might include selecting those channels of the multispectral scanner that exhibit tonal differences for transmission to the ground, recording visual observations of the target, developing film, and packaging data for return to the surface.

Table 1-14. Typical Crew Task Durations

Crew Member	Installation & Checkout Equipment (min)	Take Data (min)	Quick-look Evaluation (min)	Shutdown (min)	Evaluate Data (min)	Maintenance and Repair (min)	Typical Task of Crew Member
Resource Sci I	0	220	60	0	500	0	locate targets
Resource Sci II	0	60	60	0	500	0	evaluate "seeing"
Resource Sci III	240	220	60	0	0	0	monitor outputs
Optical Tech	240	15	0	120	60	60	cameras
Electronic Tech	600	30	0	60	60	60	electronics
Mechanical Tech	500	15	0	120	0	30	cyrogenics
Photo Tech	240	0	60	180	400	30	photo develop.

1.7.2.6 Maintenance. Both scheduled and unscheduled maintenance will be performed. Scheduled activities will include cleaning and servicing the optics and deployment mechanisms. Corrective maintenance will be performed as required. In a long-duration mission, characterized by extended periods between data-taking, a degree of fault isolation can be accommodated, provided that equipment and spares are available. This activity will be limited to replacement of modular units, bulbs, and small parts.

1.7.3 SKILLS. The distribution of the scientific and technical skills among the Experiment Areas is illustrated in Table 1-15. Each instance where a skill is utilized for an experimental area is indicated by an X in the proper row and column. The most-used experimental skill is the meteorologic, used in Areas I, III, V, and VI. On the other hand, the cartographic and geographic skills are used only for Area II, World Land Use Mapping. The photo technician is indicated for those areas where photo interpretation is part of the onboard analysis.

Ideally, the skill should be provided by a single individual who is a specialist in the field. Practically, however, one individual probably will cover several disciplines. Examples are a geographer who does research in agriculture, hydrology, and geology, or an electro-optical technician.

Table 1-15. Commonality of Skills Among Experiment Areas

RECOMMENDED SKILL AREAS	EXPERIMENT AREA NO. I	II	III	IV	V	VI	VII
Meteorologic	X		X		X	X	
Oceanographic	X		X			X	
(Cartographic		X					
							T.B.D.
Geographic)		X					T.B.D.
Geologic		X		X	X		T.B.D.
Agronomic				X	X		T.B.D.
Hydrologic			X		X		T.B.D.
Optical Technician	X	X	X	X	X	X	X
Electromechanical Tech.	X	X	X	X	X	X	X
Photo Technician		X		X	X		X

1.8 SCHEDULES

The projected schedule for the manned Earth Orbital Laboratory program is shown in Figure 1-14.

1.9 PRELAUNCH SUPPORT REQUIREMENTS AND GSE

Items of ground support required to support the launch of the facility are listed in Table 1-16.

1.10 SAFETY ANALYSIS

None of the instrumentation or experimental techniques have an inherent safety hazard. However, three possible types of accidents have been identified that might cause a hazard:

a. Bursting of liquid nitrogen dewars due to inadequate venting.

b. Accidental ignition of film.

c. Spills of corrosive photo-development chemicals.

The accidents can be avoided by proper crew training and handling procedures and the provision for automatic alarms and hazard containment, such as:

a. Fail-safe dewar venting.

b. Contaminant detection devices.

c. Fire-resistant materials.

d. Handy fire extinguishers.

e. Rapid isolation of faulty equipment.

f. Rapid containment of spills or leaks.

1.11 AVAILABLE BACKGROUND DATA

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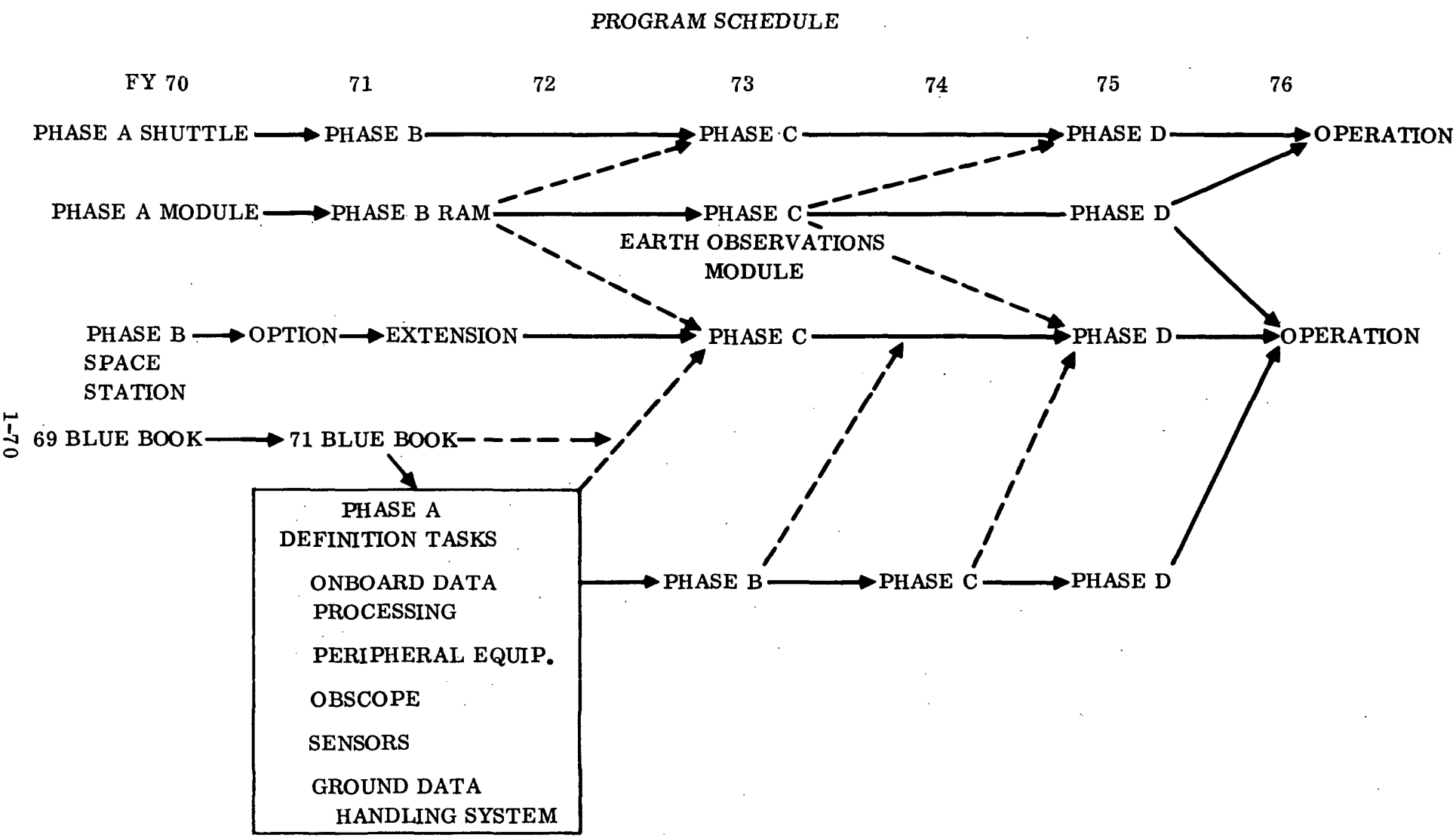


Figure 1-14. Earth Observations Manned Earth Orbital Laboratory

Table 1-16. Ground Support Equipment

Handling and Transportation	Mechanical	Electrical	Facility Support	Communication	Servicing	Environmental Control	Flight Control
Trailer - Group	Weight and Balance	Power Supply - Group	Non-Spark Tool Kit	RF Test Bench	LN_2 Service - Group	Low Pressure, Gas Test Bench	EFC Attitude Control Console - Group
Lifting Sling - Group	Alignment Fixture	Squib Test - Group	Work Platforms	Communications Test Station	Flush/Purge - Group	ECS Checkout - Group	Computer Test Console
Adapter - Group	Proof Loading Fixture	Battery Power Supply	Equipment Tie-Down Group	Headset/Microphone - Group	Emergency Service Console	Cold Trap - Group	Platform Alignment - Group
Protective Covers	Control Force Indicator	Load Simulator - Group	Assembly/Disassembly Fixture	Antenna Test - Group	Calibration - Group	Gas Sampling Kits	Inertial Platform Test Console
Dolly - Group	Passenger/Cargo Restraint Tester	Battery Maintenance - Group	Pitch/Roll Test	Field Noise Analyzer	Adapter Checkout - Group	CO_2 Auxiliary Absorber	Memory Loader and Verifier
Adapter - Group	Cargo Loading and Unloading - Group	Docking System Test - Group	Cabling - Group	Time Domain Reflectometer	Nitrogen Pressure Unit	Auxiliary N_2 Supply - Group	IGS Test Bench
LN_2 Air Transporter	ECS Installation Fixture	Squib Simulator - Group	Junction Box - Group	RF Test Set - Portable	Vacuum Drier Unit	Leakage Tester - Group	Calibration Kit - Group
Propulsion Module Transporters		UCDC and Software	Cable Support - Group	Amplifier - Group	Hydraulic Fluid Service - Group	ECS Remote Control Panel	Three-Axis Platform Dolly
Cargo Module Transporter				Intercom Tester	Ground Coolant Unit	Hose - Group	Hand Controller Tester
Cargo Shipping Pallet				Communications Monitor	Coolant Checkout Unit	Software - UCDC	Ground Station
Cargo Loading Pallett					Coolant Service - Group		Accelerometer Test Unit
Booster Simulator					Cargo Service - Group		Rate-Table Rate Gyro
Orbiter Simulator					Conditioned Makeup Air		Rate Gyro Adapter
Tunnel Fixture							
Docking Simulator							
Miscellaneous Sling, Beams							
Emergency Landing Package							

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